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ASSESSMENT FOR FUTURE ENVIRONMENTAL PROBLEMS - AGRICULTURAL RESIDUES

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This assessment was undertaken to determine whether agricultural burning constitutes an environmental problem in the United States. Preliminary indications are that agricultural burning is not likely to become a national problem.

The report summarizes available information on location, types, and quantities of residues burned; health effects; nonhealth related concerns; policies, regulations, and smoke management plans affecting agricultural burning; and alternative disposal practices. A qualitative analysis discusses the future of agricultural burning on a regional basis, taking into account factors such as agricultural production potential and demographic changes. A trend analysis computer model is used to examine the potential future emissions of particulates, hydrocarbons, and carbon monoxide from agricultural burning in California and in the Willamette Valley, Oregon.

The report concludes by identifying gaps in information, recommending methods to gather the missing information, and identifying and prioritizing research efforts. An annotated bibliography of over 100 references is provided.

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PREFACE

In order to assess the current and potential future status of open field burning of agricultural residues (agricultural burning) as a national environmental issue, EPA authorized a preliminary study to determine the importance of the practice as a source of air pollution, and to identify research needs which should be supported by the Federal Government. Information used to complete the assessment was limited to readily available literature sources and to personal communications with environmental control department and agricultural extension personnel in several states. The most intense scrutiny was given to the literature which appeared to be most pertinent to the objectives of the study and to the states where agricultural burning was most widely practiced. However, for some items apparent discrepancies in the data were identified, each requiring further study for resolution. For other items, data were insufficient to develop conclusions; as a result, additional research is needed. An annotated bibliography provides an extensive and comprehensive source list of references dealing with agricultural burning.

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ABSTRACT

This assessment was undertaken to determine whether agricultural burning constitutes a present or potential future environmental problem in the United States, and, if it does, to identify additional research needs that should be given a high priority. An important role of the Federal Government would be to support the high priority research needs to fill any large data gaps identified in the report.

The scope of the study was to review available literature concerning various aspects of the practice. Also, various Federal, State, and local environmental and agricultural department officials were contacted for additional information. Although data did not permit definitive determination, preliminary indications are that agricultural burning is not nor is likely to become a problem of national scale, but has the potential to pose serious issues for regions and States at the local level. However, additional research that is national in scope is needed before a policy decision concerning agricultural burning is made.

The report summarizes available information in the following areas: location, types, and quantities of residues burned; health effects; nonhealth related concerns; policies, regulations, and smoke management plans affecting agricultural burning; and alternative disposal practices. A qualitative analysis discusses the potential future of agricultural burning on a regional basis, taking into account a number of factors such as agricultural production potential and demographic changes. A trend analysis computer model is used to examine the potential future emissions of particulates, hydrocarbons, and carbon monoxide from agricultural burning in California and in the Willamette Valley, Oregon. (Results are included as an appendix to the report.)

The report concludes by identifying gaps in information, recommending methods to gather the missing information, and identifying and prioritizing research efforts. An annotated bibliography of over 100 references is provided.

SECTION 1.0

INTRODUCTION

The combustion of residues remaining in the field after harvest (and, in the case of sugar cane, before harvest) is practiced in many parts of the country. Among the benefits of burning are residue removal and disposal, and field sanitation. In addition, burning is often the least costly means of achieving these benefits. The emissions from residue fires, however, may result in the deterioration of air quality, creating potential adverse health impacts, visibility reduction, hazardous traffic conditions, soiling of property, and other undesirable effects.

The primary objective of the study was to determine whether agricultural burning is a current or a potential future environmental problem from a national perspective, and, if so, to identify the research and policy alternatives available to address the problem. The study also sought to identify gaps in data, data collection, and analysis techniques. In addition, an objective of the study was to create an annotated bibliography for use in further research.

In 1977, the Environmental Protection Agency (EPA) published a report on agricultural burning entitled "Source Assessment: Agricultural Open Burning, State of the Art." The objective of the report, which was written for EPA by the Monsanto Research Corporation, was to "assess the environmental impact of agricultural open burning and to produce a state of the art report summarizing available data on air emissions from this source." Information in the report included a process description of the evolution of emissions from agricultural burning, factors affecting these emissions, geographic distribution of agricultural burning and its emissions, emission estimates and characteristics, and pollution control technology.

In addressing its objectives, the current study was able to draw upon some of the information developed in the earlier report. However, most of the information required expansion and updating. Further, the current study attempts to assess the potential for future environmental problems to a greater extent than the previous study. The report includes a qualitative trend analysis for the nation based upon literature and personal communications. Also, an attempt was made to develop a quantitative trend analysis. To this end, the FUTURSCAN trend impact analysis model was used to predict the status of the practice in year 2002. The FUTURSCAN analysis was conducted only for California and Oregon data, as input data were insufficient for other states. Input data for these two states also were limited. Consequently, the usefulness of the FUTURSCAN results, contained in Appendix A, is limited.

SECTION 2.0

SUMMARY AND CONCLUSIONS

2.1 SUMMARY

Literature review and personal communication were used to form the data base for the study. First, a search of computerized data bases was conducted to identify available literature. The list of sources obtained was augmented by the project consultant. All obtainable information was reviewed and analyzed by the project staff and consultant. Persons recommended by the project consultant or located by project staff were contacted to obtain information useful for establishing current status and future trends. These persons included researchers, environmental control and agriculture department personnel, and agricultural extension personnel at university and local, State, and Federal government levels.

All information was reviewed and is summarized in the following report. Literature pertinent to agricultural burning which was obtained during the course of the project was annotated and placed in a bibliography (Section 11.0 of this report).

Agricultural burning is the primary residue disposal method for certain crops, especially for sugar cane, rice (in California), orchard prunings, and grass straw, for which economically and agronomically acceptable alternatives either are limited or unavailable. It is practiced to varying degrees in different parts of the United States, most heavily in the Southeast and concentrated areas of the West, and least in the Northeast.

Crop residues typically burned in one region may be disposed of by other means elsewhere. For example, rice straw is usually burned in California but incorporated into the soil in Mississippi. Several factors influence determination of the primary disposal method used. Chief among these appear to be tradition, climate, type of crop, disease/pest control benefits afforded, soil improvement, and farming practice (e.g., double cropping).

Benefits associated with agricultural burning include residue disposal; disease and pest control, including preventing spread of disease and pests into new areas; and low cost relative to alternative methods. Also, successive crop yields usually are maintained at a higher level when residues are burned rather than disposed of by other means. Most alternatives provide only one or a few of these benefits.

Negative impacts include air pollution and potential adverse health effects. The major pollutants associated with agricultural burning smoke are particulates, most of which are submicron in size, carbon monoxide, and hydrocarbons. Mutagens, carcinogens, and compounds suspected of being carcinogens have been identified in the smoke from certain residues. Emissions are seasonal, occurring in most areas during late summer and autumn. Where agricultural burning is used, its emissions are likely to constitute only a small proportion of the state's total emissions from all sources. However, it may constitute a large proportion in a localized area, such as the agricultural valleys in western states. These valleys are subject to frequent temperature inversions and most are located near highly populated areas. As a result, significant populations are at risk of exposure to concentrated levels of pollutants. Synergistic reactions resulting from mixture of constituents of agricultural burning smoke and other pollutants are possible, but little data exist from which to form conclusions.

Little research has been conducted to identify harmful health effects of agricultural burning, and existing research findings are inconclusive as to whether harmful effects do in fact occur. Evidence suggests that eye irritation and respiratory difficulties may occur in more sensitive persons. Existing research findings, however, are inconclusive as to whether harmful effects do in fact occur, and conclusions based upon data are thus limited in scope and reliability.

The alternatives to agricultural burning that appear to demonstrate the most promise are alternative disease, pest, and weed controls, energy production, and replacement with crops whose residues can be disposed of without burning. Each of these alternatives has drawbacks which limit application either for a particular crop or region of the country.

The bulk of available information about agricultural burning and alternative disposal methods has resulted from research conducted in areas, primarily a few western states, where the practice has been perceived as an environmental problem. Much of the research has been specific to the crops and environmental variables particular to these areas. The findings, therefore, may not be uniformly applicable to other parts of the country. For example, emission factors calculated for sugar cane in Hawaii were found not to be applicable for Florida or Texas.

Regulation of agricultural burning varies widely among the states. The degree of regulation is affected primarily by the proximity of agricultural burning to population centers, prevailing meteorological conditions, and the importance of agriculture to the state. Scheduling burns to coincide with favorable meteorological conditions predates the use of regulations. It remains a technique of primary importance for improving dispersion of smoke to minimize human exposures and other negative impacts of burning. In order to control emissions and reduce human exposures, the states which have produced most of the literature have instituted smoke management programs. Techniques developed and/or used in these programs, including scheduling burns to coincide with favorable meteorological conditions, appear to represent the best methods and technology currently available. The principles used should be applicable to other regions.

The existence of significant gaps in information, especially concerning exposures and actual health impacts, precludes definitive conclusion concerning the importance of agricultural burning as a national environmental problem. More study is necessary in order to establish whether agricultural burning is a significant national environmental problem requiring Federal intervention. The results of this study, which should be considered as preliminary, indicate that agricultural burning is not a nationwide environmental problem. Rather, it is a practice which produces emissions of local or state concern in areas where it is used. At present, there are regulatory mechanisms available at the non-federal level for controlling emissions from agricultural burning. Efforts at the Federal level should be directed primarily toward research to determine exposures and health impacts.

2.2 CONCLUSIONS

From a review of the available information, some conclusions can be drawn about the practice of agricultural burning, health effects, and the adequacy of the data base available for this study.

2.2.1 Current and Future Status of the Practice

Agricultural burning is an important agronomic practice to certain areas of the nation. Its use is likely to continue, barring discovery of major adverse health impacts associated with exposure to its smoke. As stated above, viable alternatives for certain crops or in some areas are limited. Other major factors that could influence the growth or decline of the practice include increases in agricultural production, continued population shifts, and development of alternative disposal methods.

Agricultural burning is likely to decrease in California and Oregon due to continued efforts to discover and implement viable alternatives and to limited potential for increases in agricultural production. Increased competition for markets likely will result in a decrease of sugar cane production in Hawaii and, hence, a decrease in sugar cane burning. In the Southeast region, large acreage available for agricultural production is likely to result in more acres of residues being burned. Population shifts toward the West and Southeast regions will likely increase public exposures and disagreements between farmers and non-farmers. In the West, smoke management programs are in effect to manage these problems. In the Southeast region, agricultural burning currently is practiced with much less reliance on smoke management techniques. If total acres burned and populations increase as expected, pressures to reduce emissions and human exposures will likely result in adoption of some form of regulation. As in the West region, Southeast states appear to have mechanisms to manage emission control programs.

2.2.2 Health Effects

Little research has been conducted specifically to document health effects from agricultural burning, and the findings from these studies are inconclusive. Therefore, conclusions based upon data are limited in scope and reliability.

Common observation indicates that short-term eye and respiratory irritations may occur as a result of exposure to agricultural burning smoke. Long-term impacts of exposure are unknown; however, the smoke is composed primarily of particulates, carbon monoxide, and hydrocarbons. Much of the particulate burden is submicron in size and is easily deposited deep in the lungs. Known and suspected carcinogens and some trace metals have been identified in the smoke emitted from some residues. The presence of these materials suggests a potential for adverse health impacts.

Health effects data in general are insufficient to determine long-term impacts associated with exposure to airborne carcinogens. While agricultural smoke can be a source of materials to which the local populations could be exposed, it is only one among many potential sources on a nationwide scale. Research programs are underway to identify health impacts of criteria pollutants and airborne carcinogens, and the identification of agricultural fire smoke as a source of potentially harmful pollutants underscores the need to continue these research efforts. Health effects information specific for agricultural burning should be used to supplement ongoing research.

2.2.3 Information Base

Significant gaps in available information have precluded drawing final conclusions about the importance of agricultural burning as a nationwide source of air pollution. Analysis showed that most available and reliable information pertained to agricultural burning in California, Oregon, and Hawaii. Whereas, sources with nationwide information about crops, location, and quantities burned contained numerous inconsistencies.

A more reliable analysis of the importance of agricultural burning as an agronomic practice and a source of air pollution could be completed if a new data base were created or even if the reliability of the existing data bases could be verified. A uniform approach to collecting specific information would provide a data base suitable for developing a clear picture of agricultural burning and other residue disposal methods. The U.S. Department of Agriculture annually conducts a census of agricultural statistics. A section added to this census could provide the desired data base. Alternatively, a nationwide survey of agricultural extension agents or agriculture department officials in county offices could provide a reasonably accurate description of the practice.

As earlier discussed, little information was available concerning health effects associated with agricultural burning. No information was contained which was useful for describing socio-economic impacts. The initial literature search produced reports concerning energy production from burning of agricultural residues; however, little of this information could be obtained or analyzed under the scope of the present study.

2.2.4 FUTURSCAN

Because adequate input data were unavailable and the agricultural burning problem is so complex, the FUTURSCAN results are not very useful. Thus they are included only as an appendix to this report (Appendix A). Insufficient historical data and difficulty in determining the technical relationship between events and their impacts (due to the large number of crop types, large number of outside factors affecting crop shifts, and the different effects the same event has on different crops) limit the usefulness of the results. Also, the results give little new information that is not already apparent from a careful study of the input data and event parameters. Furthermore, the probabilities of events vary among states, and the impacts of events vary among crops and states. Thus, it is only feasible, at best, to use a futures model of agricultural burning for small geographic areas, such as the Willamette Valley in Oregon. These results are not applicable to other parts of the country for several reasons, including the absence of an event concerning increased agricultural production. That particular parameter was not considered for this study because increased production in the two study areas (California and Oregon) is questionable.

SECTION 3.0

RECOMMENDATIONS

The following recommendations prescribe research needed to assist EPA in deciding whether agricultural burning constitutes a present or potential future national environmental problem in the United States. Agricultural burning is, primarily, an air pollution problem. The Clean Air Act defines air pollution problems that befit Federal action, and it describes appropriate actions the Federal government should take with respect to air pollution problems. The Clean Air Act specifies protection of public health as EPA's top priority with regard to air programs. Thus EPA's top research priorities should include filling data gaps relating to health effects associated with agricultural burning. Secondary priority should be given to research that would assist EPA or the States in developing appropriate regulatory responses. Such research priorities are further suggested by the relatively larger gaps that exist in the health effects information.

The following are research recommendations listed in order of priority.

1. Improve data base concerning potential health impacts of agricultural burning. As stated in Section 2, little data exist in this area. Evidence suggests that eye irritation and respiratory difficulties may be caused by agricultural burning smoke. However, epidemiological studies have not supported this evidence. Smoke assays have identified toxic compounds in agricultural burning smoke; however, data concerning human exposures and health impacts are incomplete.

To improve the body of information, the Federal Government should support air pollutant risk assessments, according to the steps itemized below:

- Conduct smoke assays and determine emission fact specific hazardous compounds in smoke for crops whose residues typically are burned in the largest quantities or in areas appearing to have the highest probability for human exposure to smoke;

- For use in estimating ambient air concentrations and population exposures, develop air pollution dispersion models applicable to agricultural burning area sources;

- Conduct source characterization studies for crops selected as described above. These studies should contribute to the development of a uniform national data base for all crops burned. The studies could be undertaken as part of the annual census conducted by the U.S. Department of Agriculture, or they could consist of surveys of agricultural extension agents and local agriculture department officials. The studies should provide information including the location of sources (given in latitudinal and longitudinal coordinates), areas of specific types of crops grown and harvested per source, tons per acre of residue generated, annual burn periods, and descriptions of physical characteristics of agricultural burning sources, including burning technique, fuel heating value, heat loss, moisture content of residue, flame height, temperature and wind speed, and fire propagation rate;

- Conduct toxicological, or where feasible, epidemiological studies to verify suspected short-term impacts of intrusions (e.g., eye and respiratory irritation), and to develop risk factors (if not already developed with regard to other sources of the same pollutant) for hazardous components of agricultural burning smoke. Synergistic effects also should be investigated;

- Use risk factors, and pollutant dispersion and population exposure (population information should be available) models to determine annual health effect incidence and maximum lifetime risk for specific hazardous compounds in smoke for crops selected as described above.

2. Actively encourage development and implementation of smoke management techniques. Smoke management techniques appear to be the best available techniques for limiting emissions where agricultural residues are burned. These techniques have been implemented successfully in California, Hawaii, Oregon, and Washington and could be adapted for use elsewhere, especially in the Southeast.

To promote smoke management techniques, the Federal Government should direct efforts toward:

a. Development of a guideline document for State air pollution control and agriculture department personnel explaining smoke management techniques, appropriate applications, and costs and benefits, with complete instructions on their use. Specifically, these reports should contain the following types of information:

- description of smoke management techniques and alternative methods (both tried and untried);
- description of regions and crops where methods are used or may be appropriate for use;
- critical factors that affect the feasibility of implementation, discussion of transferability to other areas;
- instruction for adapting techniques to accommodate local or regional needs;
- the kinds of impacts the methods have on:
    - emissions;
    - safety;
    - cost to the farmer;
    - agronomic and other benefits that burning provides;
    - other environmental and economic factors;
    - smoke plume characteristics;
- critical factors that affect the above impacts;
- instructions for developing a smoke management plan and incorporating the plan into the State's body of regulations; and
- whom to contact for further information.

b. Development of a guideline document to introduce smoke management techniques to farmers, including information listed above that would assist farmers in implementing the techniques.

c. Implementation of outreach programs to farmers to explain and encourage the use of smoke management techniques. Workshops, provided through agricultural extension agencies and using guideline documents described above, should be provided to farmers.

3. Support research into alternative methods of residue disposal. Research already is underway in certain areas. One particularly promising alternative is substitution of meadowfoam grass for ryegrass in Oregon. Further market assessment and breeding experiments are necessary to assess the value of meadow foam and increase its agronomic suitability to Oregon soils. Further research also is needed in Oregon and elsewhere concerning alternative disease, pest, and weed controls; research efforts in these areas have been slow due to high costs and the long-term nature of the experiments.

Energy production from residues in California already has shown success. Further research is required to determine the energy-producing value of other promising residues, particularly those from prunings, rice, and field crops.

Whole cane stalk cleaners have shown promise in Louisiana, however, more study is needed to demonstrate their value under field conditions and for different conditions of cane stalk.

SECTION 4.0

EXTENT TO WHICH BURNING OF AGRICULTURAL RESIDUES IS PRACTICED

The purpose of this section is to provide a brief overview of the geographic distribution of agricultural residue burning in the United States. In addition, major crops whose residues are typically burned, residue generation factors, and emission factors for a number of crops are identified.

4.1 BACKGROUND

Various sources of information were used in order to develop an overall view of the extent of agricultural burning in the United States. Three reports were reviewed initially: "Emissions Inventory from Forest Wildfires, Forest Managed Burns, and Agricultural Burns,"[1] "An Evaluation of the Use of Agricultural Residues as an Energy Feedstock, Volume II" (Stanford Research Institute),[2] and "Source Assessments Agricultural Open Burning, State of the Art,"[3] which expands upon Yamate's work with several gross assumptions. In addition, data concerning estimated agricultural residue burning emissions was obtained from the National Emissions Data Systems (NEDS).[4] These data are also based on Yamate's

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1. Yamate, George. 1974. Emissions Inventory from Forest Wildfires, Forest Managed Burns, and Agricultural Burns. EPA-450/3-74-062, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 34 pp.

2. Stanford Research Institute. 1976. An Evaluation of the Use of Agricultural Residues as Energy Feedstock, Volume II. NSF/RA-760287. National Science Foundation, Washington, D.C. 595 pp.

3. Chi, C.T., and D.L. Zanders. 1977. Source Assessment: Agricultural Open Burning, State of the Art. EPA/600/2-77-107a, Industrial Environmental Research Lab, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 77 pp.

4. National Emissions Data System. 1981. Office of Air Quality Planning and Standards. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina.

original work but have been adjusted since 1974 by using assumed annual factors. Finally, personal contacts with state personnel and agricultural extension agents were made to assess the current and future status of agricultural burning.

The following sections present information found in the reports for the United States as a whole and then discuss the extent of agricultural burning for each region based upon the personal communications. Of the four sources of data, only two are completely independent -- the Yamate report and the SRI report. Both the Monsanto report and the NEDS data use Yamate's work as a basis. The NEDS data differ from Yamate's only by a modification that was made between 1978 and 1979. EPA Monitoring and Data Analysis Division was unable to explain the reason for the change. The purpose may have been to keep up with national emissions trends. Monsanto also used Yamate's data (rounding off the numbers), but went beyond Yamate's work and estimated tons of residue for states not covered by Yamate. Monsanto's additional data were inferred using state emission inventories from Montana and New Mexico, national burning totals from Yamate, and agricultural statistics. Yamate's data were obtained from the U.S. Forest Service, the Bureau of Land Management, Bureau of Indian Affairs, and various state forestry, agricultural, and environmental agencies. Yamate's data was gathered to complete the NEDS area source inventories on emissions from forest wildfires, forest managed burns, and agricultural burns for each of the 55 states and territories.

The SRI data were gathered as part of a study to evaluate the use of agricultural residues as an energy feedstock. The SRI report used the term "wasted" to include residues that must be disposed of at an economic cost, i.e., hauled away, burned, etc. The category includes all logging residues as well as collected residues that are not sold, fed, or used as fuel, i.e., they are returned to the soil at an economic cost. For the sake of convenience, the terminology "residue burning" is inclusive of sugar cane burning which occurs before harvest rather than after harvest.

4.2 GEOGRAPHIC DISTRIBUTION

Agricultural burning is not practiced uniformly across the United States (Table 1). Estimates as to the extent of its use presented in

Table 1. COMPARISON OF ESTIMATES OF THE DISTRIBUTION OF AGRICULTURAL BURNING, IN THE UNITED STATES

Region/State	Acres Burned Per Year				Tons Burned Per Year			
	Yamate[1]	SRI[2,a]	Monsanto[3,b]	NEDS[4,c]	Yamate[1]	SRI[2,a]	Monsanto[3,b]	NEDS[4,c]
Northeast								
Connecticut	0		NR	0	0	845	NR	0
Delaware[d]	210		200	178	2,100	322[e]	2,000	1,780
Maine[d]	36,400		36,000	31,265	36,400	852[e]	36,000	31,265
Maryland[d]	1,500		1,500	1,288	7,500	2,195[e]	8,000	6,440
Massachusetts	ND		1,500	0	ND	1,466[e]	3,000[f]	0
New Hampshire	0		NR	0	0	734[e]	NR	0
New Jersey	0		NR	0	0	3,737[e]	NR	0
New York	0		NR	0	0	14,823[e]	NR	0
Pennsylvania	ND		38,000	0	ND	8,103[e]	76,000[f]	0
Rhode Island	0		NR	0	0	151[e]	NR	0
Vermont	100		NR	85	300	0	NR	255
West Virginia	0		NR	0	0	26,572[e]	NR	0
Subtotal	38,210		77,200	32,815	46,300	59,810	125,000	39,740

Key: NR = not reported
ND = no data available
NEG = negligible

Table 1. COMPARISON OF ESTIMATES OF THE DISTRIBUTION OF AGRICULTURAL BURNING, IN THE UNITED STATES (Continued)

Region/State	Acres Burned Per Year				Tons Burned Per Year			
	Yamate	SRI	Monsanto	NEDS	Yamate	SRI	Monsanto	NEDS
Midwest								
Illinois	NEG		NR	0	ND	4,206^{g}	NR	0
Indiana	NEG		NR	0	ND	1,584^{g}	NR	0
Iowa	NEG		NR	0	ND	213^{g}	NR	0
Kansas^{d}	600,000		600,000	493,725	600,000	281^{e}	600,000	493,725
Michigan	ND		51,000	0	ND	19,045^{e}	102,000^{h}	0
Minnesota	ND		151,000	0	ND	5,976^{h}	302,000^{h}	0
Missouri	ND		100,000	0	ND	18,956^{i}	200,000^{h}	0
Nebraska	ND		167,000	0	ND	45^{e}	334,000^{h}	0
North Dakota	ND		242,000	0	ND	4	484,000^{h}	0
Ohio	ND		79,000	0	ND	2,995^{e}	158,000^{h}	0
South Dakota	ND		146,000	0	ND	29	292,000^{h}	0
Wisconsin	ND		80,000	0	ND	7,042^{g}	160,000^{h}	0
Subtotal	600,000		1,616,000	493,725	600,000	70,531	2,632,000	493,725

Table 1. COMPARISON OF ESTIMATES OF THE DISTRIBUTION OF AGRICULTURAL BURNING, IN THE UNITED STATES (Continued)

	Acres Burned Per Year			Tons Burned Per Year				
Region/State	Yamate	SRI	Monsanto	NEDS	Yamate	SRI	Monsanto	NEDS
South								
Alabama[d]	89,000		89,000	76,431	178,000	5,477[i]	178,000	152,862
Arkansas	ND		64,000	0	ND	1,092,918[i]	128,000[h]	0
Florida[d]	265,000		270,000	227,634	1,855,000	1,111,349[i]	1,890,000	1,593,438
Georgia[d]	974,406		974,000	836,932	974,406	18,284[i]	974,000	836,932
Kentucky	ND		32,000	0	ND	466[i]	64,000[h]	0
Louisiana[d]	350,000		350,000	287,411	2,100,000	1,586,710[i]	2,100,000	1,724,466
Mississippi[d]	340,170		340,000	273,725	680,340	120,292[i]	680,000	547,450
North Carolina[d]	341,185		341,000	293,056	682,370	2,477[i]	682,000	586,112
Oklahoma	ND		89,000	0	ND	6,597[i]	178,000[h]	0
South Carolina	ND		21,000	0	ND	4,428[i]	42,000[h]	0
Tennessee	ND		34,000	0	ND	393[i]	68,000[h]	0
Texas	NEG		NR	0	ND	1,085,202[i]	NR	0
Virginia	ND		24,000	0	ND	5,766[e]	48,000[h]	0
Subtotal	2,359,761		2,628,000	1,995,189	6,470,116	5,040,359	7,032,000	5,441,260

Table 1. COMPARISON OF ESTIMATES OF THE DISTRIBUTION OF AGRICULTURAL BURNING, IN THE UNITED STATES (Continued)

	Acres Burned Per Year				Tons Burned Per Year			
Region/State	Yamate	SRI	Monsanto	NEDS	Yamate	SRI	Monsanto	NEDS
West								
Alaska	0		NR	0	0	NR	NR	0
Arizona	ND		11,000	0	ND	10,599	22,000[h]	0
California[d]	762,862		763,000	655,267	2,288,586	1,081,153	2,289,000	1,310,534
Colorado	ND		79,000	0	ND	1,686[e]	158,000[h]	0
Hawaii[d]	108,000		108,000	92,769	1,296,000	NR	1,296,000	1,113,228
Idaho[d]	11,849		12,000	10,170	23,698	2,492[e]	22,000	20,340
Montana	ND		84,000	0	ND	126[e]	168,000[j]	0
Nevada[d]	1,950		2,000	1,674	5,850	0[i]	6,000	5,022
New Mexico	ND		1,000	0	ND	1,497[e]	2,000[k]	0
Oregon[d]	264,170		264,000	236,931	528,340	12,526[e]	528,000	473,862
Utah	NEG		NR	0	ND	0	NR	0
Washington[d]	140,801		141,000	120,937	281,602	18,331[g]	282,000	241,874
Wyoming	ND		18,000	0	ND	42	38,000[f]	0
Subtotal	1,289,632		1,483,000	1,117,748	4,424,076	1,128,452	4,811,000	3,164,860

Table 1. COMPARISON OF ESTIMATES OF THE DISTRIBUTION OF AGRICULTURAL BURNING, IN THE UNITED STATES (Concluded)

	Acres Burned Per Year				Tons Burned Per Year			
Region/State	Yamate	SRI	Monsanto	NEDS	Yamate	SRI	Monsanto	NEDS
Other								
American Samoa	NEG		NR	NR	ND	NR	NR	NR
District of Columbia	0		NR	NR	0	NR	NR	NR
Guam	0		NR	NR	0	NR	NR	NR
Puerto Rico	78,791		NR	78,791	630,328	NR	NR	630,328
U.S. Virgin Islands	0		NR	NR	0	NR	NR	NR
Subtotal	78,791		-		630,328	-	-	
Subtotals								
Northeast	38,210	-	77,200	32,816	46,300	59,810	125,000	39,740
Midwest	600,000	-	1,616,000	493,725	600,000	70,531	2,632,000	493,725
South	2,359,761	-	2,628,000	1,995,189	6,470,116	5,040,359	7,032,000	5,441,260
West	1,289,632	-	1,483,000	1,117,748	4,424,076	1,128,452	4,811,000	3,164,860
Other	78,791	-	-	78,791	630,328	-	-	630,328
Grand Total	4,365,394	-	5,804,200	3,639,478	12,170,820	6,299,152	14,600,000	9,139,585

Key: NR = not reported
ND = no data available
NEG = negligible

Footnotes for Table 1

[a] See Section 4.1 for SRI's definition of the term "wasted".

[b] Monsanto used George Yamate's work as the basis for its estimates (Monsanto's figures were rounded). Monsanto extended Yamate's work and estimated tons of residue for states not covered by Yamate.

[c] The NEDS estimate, though based on Yamate, differs from Yamate by a numerical factor that decreased the figures for amount burned after 1978.

[d] The NEDS and Monsanto estimates are both based on George Yamate's work. The NEDS data unexplainably were modified between 1978 and 1979.

[e] Primary residue "wasted" is orchard prunings.

[f] Estimated by Monsanto.

[g] Primary residues "wasted" are orchard prunings and sweet corn (shed).

[h] Primary residue "wassted" is sweet corn (shed).

[i] Excludes costton gin trash wasted.

[j] Monsanto obtained this information from "Emission Inventory for State of Montana" NTIS No. 204 383 (1971).

[k] Monsanto obtained this information from "Emission Inventory for State of Idaho" NTIS No. 204 384 (1971).

the four previously listed reports vary significantly on both a regional and state level. This variation is most likely due to different definitions of "agricultural burning," the completeness of records kept in each state, and the different people contacted in each state from whom estimates were obtained and their perception as to the importance of agricultural burning in the state. The quantified estimates consistently show that more burning occurs in both the south and west regions than in either the northeast region, which has very little agricultural burning reported, or the midwest region.

The information contained in the SRI report and NEDS data also shows that agricultural burning is in many instances localized within a state. Figure 1 shows for each state those counties that have more than 10,000 tons of agricultural residues burned as reported in the NEDS file as of July 1, 1981, and as reported as "wasted" in the SRI report. (The Monsanto and Yamate reports did not include information on a county-by-county basis and, therefore, could not be used in constructing these figures.) Standard Metropolitan Statistical Areas (SMSAs) located near these agricultural burning areas are also shown in the figures to provide an approximation of the geographic distribution of agricultural burning relative to large population areas. Figure 2 shows crop residue densities for the United States.[5] This information was developed on a county-by-county basis. Figures 1 and 2 together provide a graphic presentation of where large amounts of crop residues are generated and where agricultural burning is primarily practiced.

4.2.1 Northeast Region

From the estimates in the reports and personal communication with the Agricultural Research Service in Beltsville, Maryland, agricultural burning in the Northeastern region is almost non-existent.[6] From the SRI report and open burning regulations in this region, it appears that the agricultural burning that does take place is primarily the

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5. Gikis, Benjamin, et.al. 1978. Preliminary Environmental Assessment of Energy Conversion Processes for Agricultural and Forest Product Residues, Volume I. EPA-600/7-78-047. U.S. Environmental Protection Agency, Cincinnati, Ohio.

6. King, S. Agricultural Research Center, Maryland. November 13, 1981. Personal communication.

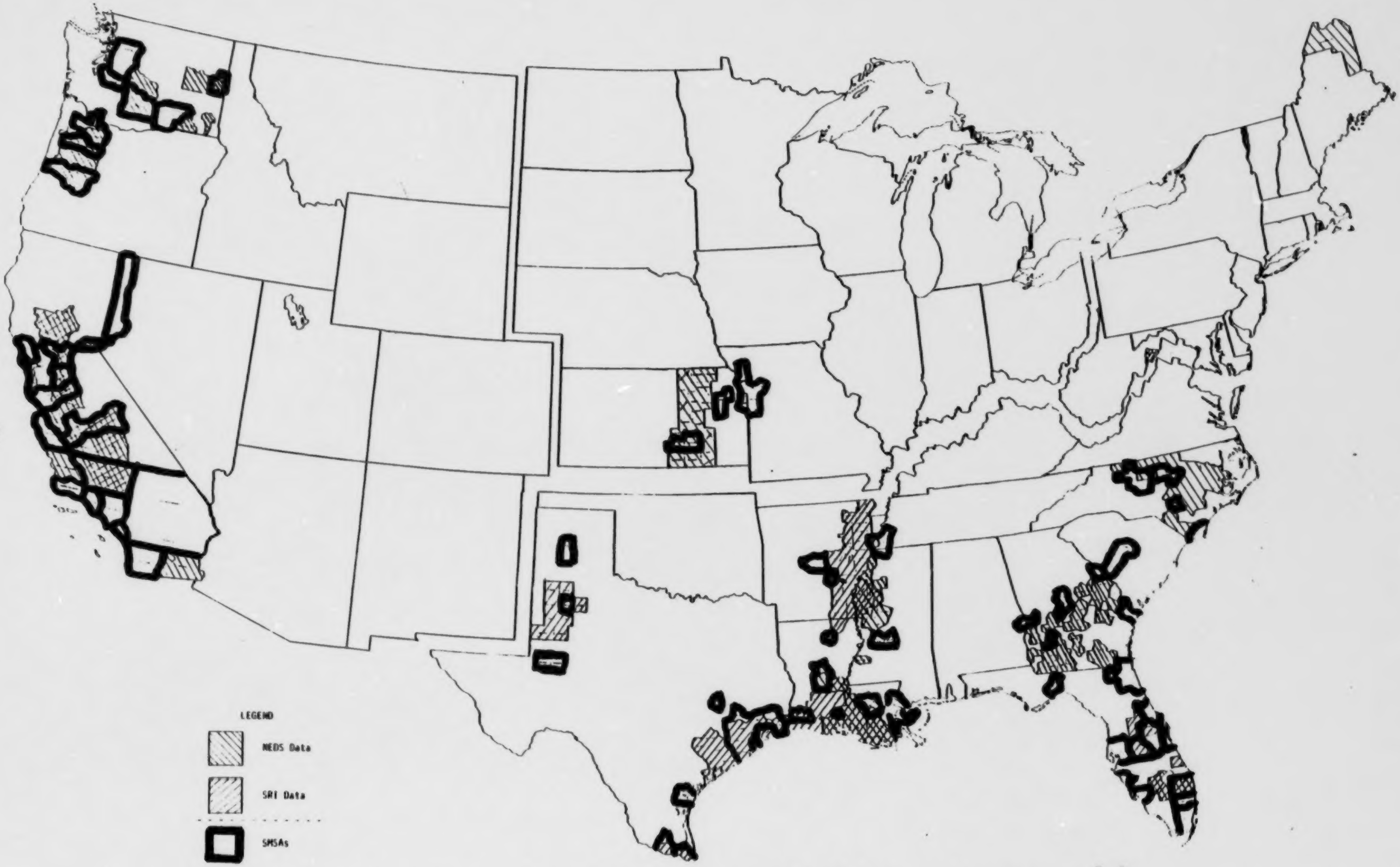
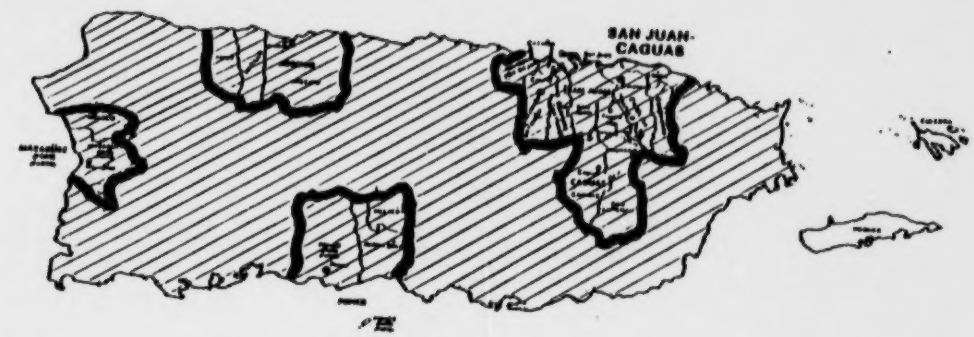

LEGEND
NEDS Data
SRI Data
SMSAs

Figure 1. Counties with more than 10,000 acres of agricultural residues burned.[2,4]


SAN JUAN-CAGUAS

Puerto Rico*

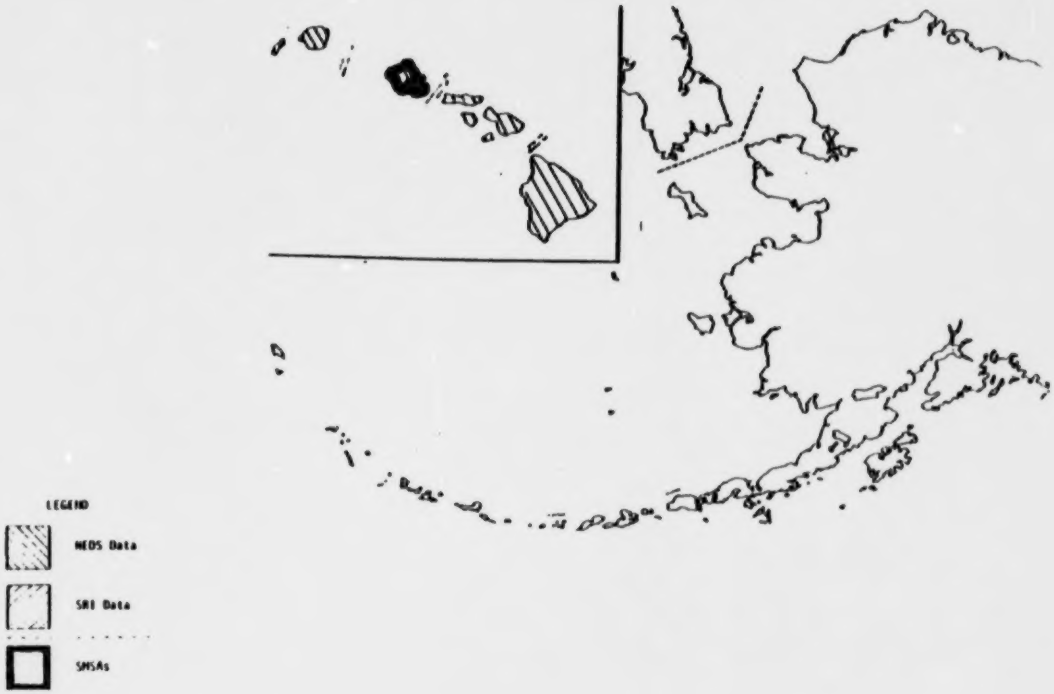

LEGEND
NEDS Data
SRI Data
SMSAs

Figure 1. (continued)
* Puerto Rico burns approximately 630,000 tons of residue per year.

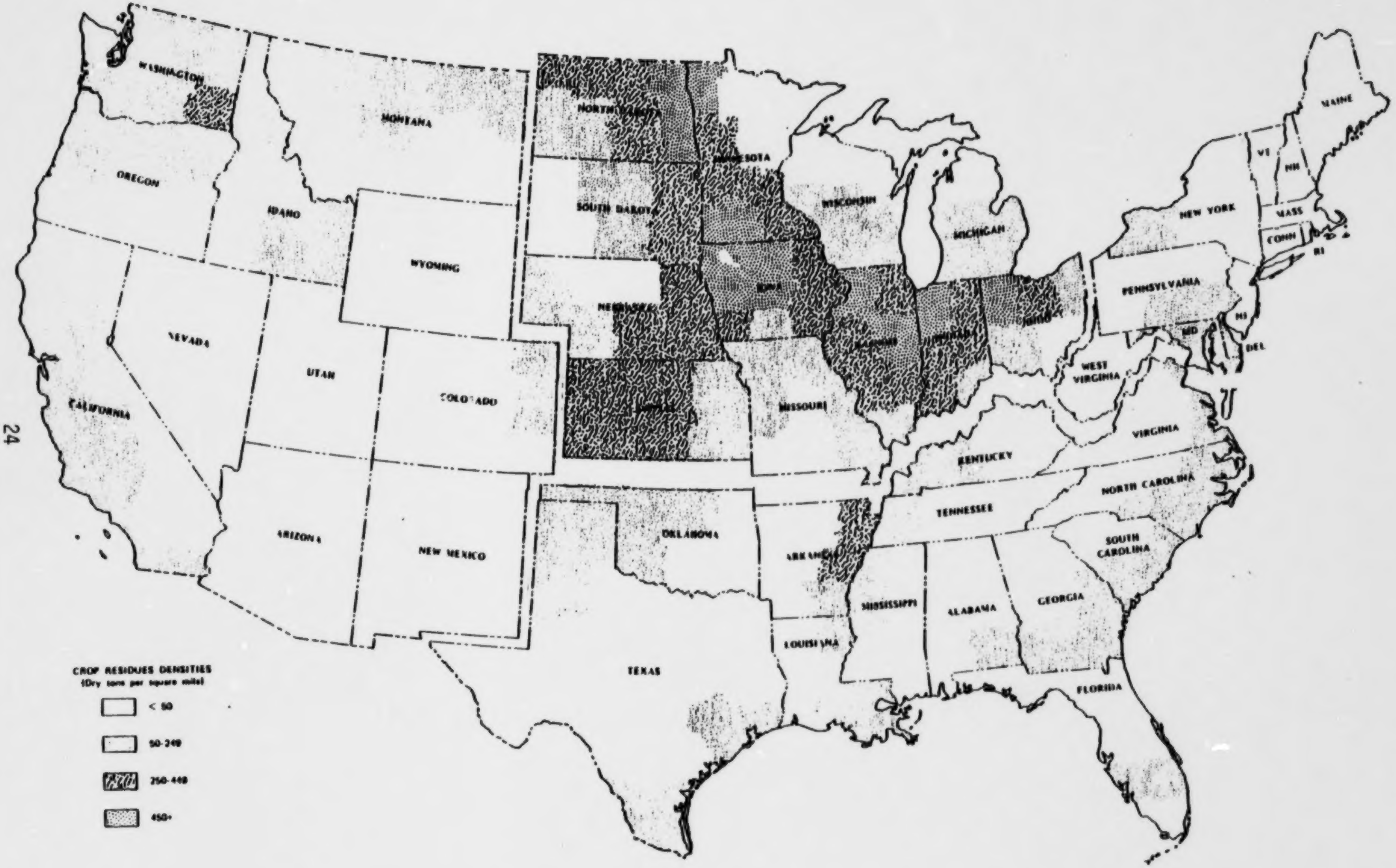

WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MD
DEL
NJ
VT
NH
MAINE
MASS
CONN
RI
CROP RESIDUES DENSITIES
(Dry tons per square mile)
< 50
50-249
250-449
450+

Figure 2. Density of Crop Residue[5]

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burning of orchard prunings. The Massachusetts open burning regulation also mentions the burning of blueberry patches and dead raspberry stalks.

4.2.2 Midwest Region

According to officials contacted in several states in this area, open field burning of agricultural residues is not a common practice in most states of the midwest region, except in Kansas, Missouri, and Nebraska wheat fields.[7] In Iowa, most residues are incorporated into the soil.[8] Crop residues usually are plowed under in Minnesota, although bluegrass residues are burned in a limited area of one county.[9] Little agricultural burning occurs in Illinois, North Dakota, and South Dakota. In North Dakota, the practice formerly was common because the quantity of residue could not be handled with available equipment. However, with the advent of high-powered tractors, most residues now are incorporated into the soil.[10]

In Kansas, Missouri, and Nebraska, open field burning appears to be a common practice, especially for wheat straw, according to estimates obtained from environmental departments or agricultural extension officials in the respective states. It is used for residue disposal on about 20 to 30 percent of the 11 to 13 million acres of wheat in Kansas.[11] The practice is widely used in Missouri's wheat fields, which are primarily located in the upper two-thirds of the state. About a decade ago, nearly all wheat straw was burned in Nebraska; currently the figure is about 5 percent.[12] The reduction has been attributed to the state's program to educate farmers that soil incorporation is more beneficial. Those who still burn residues are thought to be older generation farmers reluctant to change an established practice. As these farms change hands, burning likely will be discontinued.

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[7] Fitzgerald, P., Rhodes, Agricultural Research Center, Illinois. November 13, 1981. Personal communication.

[8] Powers, R.C. Agricultural Extension Service, Iowa. November 13, 1981. Personal communication.

[9] Krupa, S. Minnesota. November 16, 1981. Personal communication.

[10] Lund, H.R. N. Dakota. November 17, 1981. Personal communication.

[11] Ownesby, C. Agricultural Extension Service, Kanasas. November 13, 1981. Personal communication.

[12] Robinson, G. Air Pollution Control, Nebraska. November 24, 1981. Personal communication.

There are three major apparent discrepancies between the above discussion, information for which was obtained from state officials and agricultural extension agents, and the estimates from the literature. The first concerns the area in Kansas where 494,000 acres are reported in the NEDS data to be burned. As shown in Figure 2, the area coincides with the Flint Hill region, where, according to an agricultural extension agent, range is burned.[11] The amount of range burned in this area is typically around 1 to 1.5 million acres, but may be as low as 200,000 or as high as 3 million acres in any one year. It seems likely, therefore, that the acres reported by Yamate and carried over to the NEDS data actually represent range. If this supposition is correct, then the NEDS data do not indicate any wheat burning, and, therefore, underestimate the amount of agricultural burning in this State.

The two other apparent discrepancies concern Missouri and Nebraska where personal contacts indicated a fairly large amount of burning but the reports indicated very little. More study is necessary for the resolution of these discrepancies.

In summary, there appears to be a relatively small amount of burning in the Midwest region outside of Kansas, Missouri, and Nebraska. In these three states, wheat stubble appears to be the major residue burned, and the burning usually occurs in sparsely populated areas with generally favorable meteorological conditions for dispersion of smoke (with the possible exception shown in Figure 2). In addition, in places where burning does occur it is an accepted practice.

4.2.3 South Region

The reports examined in this study indicate more agricultural burning occurs in this region than any other region. Interestingly, however, almost everyone contacted in this region did not know how much burning was taking place. Resolution of the apparent discrepancy between available reports and information supplied by personal contacts was beyond the scope of this study. Little, if any, effort is made in these states to maintain records of how much burning takes place each year. Of the states contacted in this region, only Florida and North Carolina appear to maintain records of the number of acres burned for agricultural purposes (Florida) and the number of acres burned for agricultural and land clearing purposes (North Carolina).

Based on the estimates in the reports and the personal contacts, agricultural burning tends to be fairly evenly distributed within each state in this region, although some states do have highly localized pockets. Major areas of agricultural burning in this region include the Grand Prairie region in southeastern Arkansas (rice and wheat), the Lake Okeechobee Area in Florida (sugar cane), and southern Louisiana (rice and sugar cane). In Arkansas, the rice crop is alternated with winter wheat, so that burning occurs twice per year. In Mississippi, one estimate shows that approximately 20 percent of the wheat acreage, which was about 600,000 acres in 1980 and is fairly well distributed throughout the state with some concentration in the Delta region, might be burned. Another estimate is that of the 500,000 acres of land double cropped (wheat followed by soybean), about 250,000 acres of wheat are burned. About 75-80 percent of the wheat acreage is located in the northern and northeast part of the state.[13] One agricultural extension agronomist estimated that less than 1 percent of the 340,000 acres of rice planted in Mississippi is burned.[14] Instead, rice residue is normally turned under or left standing over the summer and then rolled down for re-incorporation into the soil. In Florida, almost all of the sugar cane acreage is located in Palm Beach County.

In Texas, sugar cane and wheat are the two crops of significance which are burned. There are approximately 37,000 acres of sugar cane in the Rio Grande Valley. Most of the wheat is grown in the northern plains of the state. Records of acres burned probably could be obtained from county agriculture department officials or extension agents.

In summary, burning of agricultural residues is an accepted practice in the South, where estimates show that nearly 2 million acres are burned annually. Data on quantities and locations, however, are inadequate and inconsistent. The Yamate report, for example, fails to report the large amount of burning occurring in the Grand Prairie region of Arkansas. In addition, while both the SRI report and the NEDS data show approximately the same tonnage for Louisiana, examination of the locations on the county level shows sharp inconsistencies. Other data inconsistencies occur especially for Texas and North Carolina. While there are inadequacies and inconsistencies in the Midwest and Northeast regions, they are magnified to a greater extent in this region due to the greater use of the practice. Further research may be necessary to resolve these discrepancies.

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[13] Anderson, W. Air Division, Mississippi. No date. Personal communication.

[14] Miller, T. Extension Agronomist, Mississippi. November 13, 1981. Personal communication.

4.2.4 West Region

This region has the second largest quantity of agricultural residues burned in the United States based on the estimates in Table 1. In the West, like the Midwest, the difference is very distinct between states in regard to the scale of agricultural burning practiced. Most of the burning in this region occurs in three states: California, Hawaii, and Oregon. In addition, West region states are the source of most research and some of the most complete data about the practice.

Agricultural burning in California involves numerous crops, especially rice, wheat, and almond. Rice straw has been studied more intensely than any other crop residue because of the proximity of rice fields to population centers, the large quantities burned, and the typically poor meteorological conditions during its burning season. California estimates for 1980 include 1,321,332 acres burned and 3,102,011 tons of residues burned. (Table 1 figures, other than NEDS, are not as recent. NEDS figures, however, are projections based on Yamate's figures.) Table 2 shows 1976 figures for contributions from all agricultural burning as a percent of total emissions. While distributed throughout the state, much of the burning occurs in valleys which are near large population centers (for example, Sacramento). For each of the state's air basins, California law currently stipulates various conditions under which agricultural burning may take place.

In Hawaii, most burning involves sugar cane, while a small amount of pineapple is included. Sugar cane fields are distributed fairly evenly over the islands of Hawaii, Maui, Oahu, and Kanai.

Table 2. CALIFORNIA AGRICULTURAL BURNING EMISSIONS - 1976 PERCENT OF TOTAL[15]

Emissions Type	Statewide	Sacremento Valley	San Joaquin Valley
Total organic gases (hydrocarbons)	1.4%	8.5%	2.5%
Particulates	0.8%	4.1%	1.0%
Carbon Monoxide	2.0%	9.6%	7.6%
Sulfur Dioxide	0.0%	0.0%	0.0%
Oxides of Nitrogen	0.0%	0.0%	0.0%

In Oregon, the major area is the Willamette Valley, where grass seed residues are burned. Currently, legislation allows burning of up to 250,000 acres each year in the Valley. Poor meteorological conditions during the burning season and large population centers at both ends of the Valley have contributed to making this region perhaps the most intensely researched area in the United States for methods to reduce use of the practice and exposure to its smoke.

Other specific areas in the West where agricultural burning occurs include Spokane County, Washington (approximately 26,000, acres of bluegrass),[16] eastern Idaho (approximately 10,000 acres of bluegrass),[17] and, in Montana, the Gallatin Valley (hay crops)[17] and the Flathead area (grass seed).[18] Relatively little has been noted in the other states. In Nevada, for example, burning is not recommended as a management

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15. Agricultural Residue Management: A Focus on Rice Straw. A Report of the Residue Management Task Force, University of California. 1981. 164 pp.

16. McEnany, C. Spokane County Air Pollution Control Authority, Washington. November 20, 1981. Personal communication.

17. Ensign, R.D. Idaho. November 17, 1981. Personal communication.

18. Norton, W. Air Quality Bureau, Montana. November 25, 1981. Personal communication.

tool for crops as the area is very dry; therefore, other disposal practices are prevalent.[19]

In summary, the West region contains a number of states where little burning evidently occurs (Alaska, Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming); a number of states where a moderate amount occurs (Idaho, Montana, and Washington); and a number of states where a large amount occurs (California, Hawaii, and Oregon). As much of this burning takes place close to large population areas, research has been and is being conducted into methods to reduce emissions and exposures. California, Hawaii, and Oregon especially have implemented well-developed smoke management plans.

4.2.5 Other Regions

Except for Puerto Rico, where sugar cane residue is burned, no other area appears to use the practice to any significant extent. According to NEDS data, Puerto Rico burns a total of about 630,328 tons per year of sugar cane.

4.3 MAJOR CROPS BURNED

Table 3 presents a list of the major crops whose residues are burned.

Table 3. MAJOR CROP RESIDUES BURNED

Crop	Primary Locations
Almond Trash	California
Grasses	Oregon, Washington, Idaho, California
Orchard Prunings	California, Other States
Rice	California, Arkansas, Louisiana
Sugar Cane	Hawaii, Florida, Louisiana, Puerto Rico, Texas
Wheat	California, Kansas, Missouri, Nebraska, Other States

While burning may be the primary disposal method used for a particular crop in one part of the country, another method may be prevalent elsewhere. For example, burning is the predominant method of rice straw disposal in California and in the Grand Prairie area of Arkansas, whereas, soil incorporation is the primary rice straw disposal method in the lower Mississippi Valley. This difference in practice is due mainly to the difference in environmental conditions between California and the lower Mississippi Valley and to the use of double cropping in the Grand Prairie area of Arkansas.

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[19] Bohmont, D.W. Agriculture Extension Service, Nevada. November 13, 1981. Personal communication.

4.4 ESTIMATED NATIONWIDE EMISSIONS FROM AGRICULTURAL BURNING

The air pollutant contribution of the various crop residues when burned may be estimated by multiplying the number of acres burned by the residue factor (i.e., the amount of crop residue left in the field after harvest in terms of tons per acre), which gives the total amount of residue burned (i.e., the fuel loading) and then multiplying the result by the emission factors (i.e., the amount of pollutant emitted per ton of residue burned). Table 4 presents estimates of the amounts of particulate, hydrocarbon, carbon monoxide, and nitrogen oxides from burning of agricultural residues in the United States. Figures for 1940-1970 were developed by applying factors to rough estimates of quantities of residues burned, which were obtained from state agriculture departments.[20] The 1972 and 1981 figures were obtained by summing individual state estimates provided in the Monsanto report and NEDS file, respectively. Appendix B shows the individual state figures presented in the Monsanto report. Table 5 presents estimates of the relative contribution of agricultural burning to total emissions of particulates, hydrocarbons, and carbon monoxide in states where the practice is reportedly used. The high contribution for Hawaii is evidence of the importance of sugar cane to the state's agricultural output.

The primary reference source for residue and emission factors is AP-42[21] (see Table 6). The information in this source has been compiled from research conducted primarily in California, but also in Oregon

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[20] Cavender, J.H., D.S. Kircher, and A.J. Hoffman. 1973. Nationwide Air Pollutant Emission Trends, 1940-1970. Environmental Protection Agency. Research Triangle Park, North Carolina. 52 pp.

[21] Compilation of Air Pollution Emission Factors (Revised). 1977. OAP Publication No. AP-42. U.S. Environmental Protection Agency, Office of Air Programs, Research Triangle Park, North Carolina.

Table 4. EMISSION ESTIMATES FROM BURNING OF AGRICULTURAL RESIDUES

	Tons x 10^6/Year					
	1940[a,20]	1950[a,20]	1960[a,20]	1970[a,20]	1972[b,3]	July 21, 1981[c,4]
Particulate	1.6	1.8	2.1	2.4	0.11	0.07
CO	9.1	10.4	12.4	13.8	0.66	0.48
HC	1.9	2.1	2.5	2.8	0.13	0.09
NO_x	0.2	0.2	0.3	0.3	0.01	0.01

[a] All 50 states surveyed.

[b] 37 states excluding AK, CT, IL, IN, IO, NH, NJ, NY, RI, TX, UT, VT, WV.

[c] 17 states plus Puerto Rico: AL, CA, DE, FL, GA, HA, ID, KA, LA, MA, MD, MI, NE, NC, OR, VT, WA.

Table 5. COMPARISON OF AG. BURNING EMISSIONS WITH STATEWIDE EMISSIONS[4]
(Tons x 10^3)

	PARTICULATES			HYDROCARBONS			CARBON MONOXIDE		
Northeast	Ag	State Total	%Ag	Ag	State Total	%Ag	Ag	State Total	%Ag
Delaware	.01	63	*	.02	79	*	.08	229	*
Maine	.22	137	0.16%	.26	140	0.18%	1.47	489	0.3%
Maryland	.05	219	*	.05	345	*	.3	1,573	*
Vermont	.002	93	*	.002	44	*	.01	175	*
Midwest									
Kansas	3.5	1,867	0.18%	4.17	359	1.16%	23.2	1,163	2.0%
South									
Alabama	1.09	467	0.2%	1.29	500	0.26%	7.19	2,107	0.34%
Florida	11.4	936	1.2%	13.5	841	1.61%	74.9	4,148	1.81%
Georgia	6.0	697	0.86%	7.07	575	1.2%	39.3	2,532	1.55%
Louisiana	12.3	604	2.04%	14.6	772	1.89%	81.1	2,652	3.06%
Mississippi	3.91	591	0.66%	4.63	326	1.42%	25.7	1,130	2.27%
North Carolina	4.19	746	0.56%	4.96	676	0.07%	27.5	2,544	1.08%
Western									
California	12.5	1,516	0.82%	14.7	2,530	0.58%	81.9	9,536	0.86%
Hawaii	7.6	53	14.3%	9.02	71	12.7%	50.2	325	15.4%
Idaho	.15	280	*	.17	159	0.1%	.96	930	0.1%
Nevada	.03	919	*	.04	72	*	.2	407	*
Oregon	3.39	1,823	0.19%	4.00	305	1.3%	22.3	1,430	1.56%
Washington	1.73	332	0.5%	2.04	476	0.43%	11.4	2,578	0.44%
Other									
Puerto Rico	NA**	NA	NA	NA	NA	NA	NA	NA	NA

* .%
**Not Available

Table 6. AP-42 EMISSION FACTORS AND FUEL LOADING FACTORS FOR OPEN BURNING OF AGRICULTURAL MATERIALS[a,21]

EMISSION FACTOR RATING: B

	Emissions factors							
	Particulate[b]		Carbon monoxide		Organics (as C_6H_{14})		Fuel loading factors (waste production)	
Refuse category	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	ton/acre	MT/hectare
Field crops[c]								
Unspecified	21	11	117	58	23	12	2.0	4.5
Burning technique not significant[d]								
Asparagus[e]	40	20	150	75	85	42	1.5	3.4
Barley	22	11	157	78	19	10	1.7	3.8
Corn	14	7	108	54	16	8	4.2	9.4
Cotton	8	4	176	88	6	3	1.7	3.8
Grasses	16	8	101	50	19	10		
Pineapple[f]	8	4	112	56	8	4		
Rice[g]	9	4	83	41	10	5	3.0	6.7
Safflower	18	9	144	72	26	13	1.3	2.9
Sorghum	18	9	77	38	9	4	2.9	6.5
Sugar cane[h]	6-8.4	2.5-3.5	60-81	25-33	5-16	2-6.6	3-17	8-46
Headfire burning[i]								
Alfalfa	45	23	106	53	36	18	0.8	1.8
Bean (red)	43	22	186	93	46	23	2.5	5.6
Hay (wild)	32	16	139	70	22	11	1.0	2.2
Oats	44	22	137	68	33	16	1.6	3.6
Pea	31	16	147	74	38	19	2.5	5.6
Wheat	22	11	128	64	17	9	1.9	4.3
Backfire burning[j]								
Alfalfa	29	14	119	60	37	18	0.8	1.8
Bean (red), pea	14	7	148	72	25	12	2.5	5.6
Hay (wild)	17	8	150	75	17	8	1.0	2.2
Oats	21	11	136	68	18	9	1.6	3.6
Wheat	13	6	108	54	11	6	1.9	4.3
Vine crops	5	3	51	26	7	4	2.5	5.6
Weeds								
Unspecified	15	8	85	42	12	6	3.2	7.2
Russian thistle (tumbleweed)	22	11	309	154	2	1	0.1	0.2
Tules (wild reeds)	5	3	34	17	27	14		
Orchard crops[c,k,l]								
Unspecified	6	3	52	26	10	5	1.6	3.6
Almond	6	3	46	23	8	4	1.6	3.6
Apple	4	2	42	21	4	2	2.3	5.2
Apricot	6	3	49	24	8	4	1.8	4.0
Avocado	21	10	116	58	32	16	1.5	3.4
Cherry	8	4	44	22	10	5	1.0	2.2
Citrus (orange lemon)	6	3	81	40	12	6	1.0	2.2

Table 6. AP-42 EMISSION FACTORS AND FUEL LOADING FACTORS FOR OPEN BURNING OF AGRICULTURAL MATERIALS[a,21] (Concluded)

EMISSION FACTOR RATING: B

Refuse category	Emission factors						Fuel loading factors (waste production)	
	Particulate[b]		Carbon monoxide		Organics (as C_6H_{14})			
	lb/ton	kg/MT	lb/ton	kg/MT	lb/ton	kg/MT	ton/acre	MT/hectare
Orchard crops[c,k,l] (continued)								
Date palm	10	5	56	28	7	4	1.0	2.2
Fig	7	4	57	28	10	5	2.2	4.9
Nectarine	4	2	33	16	4	2	2.0	4.5
Olive	12	6	114	57	18	9	1.2	2.7
Peach	6	3	42	21	5	2	2.5	5.6
Pear	9	4	57	28	9	4	2.6	5.8
Prune	3	2	42	21	3	2	1.2	2.7
Walnut	6	3	47	24	8	4	1.2	2.7
Forest residues								
Unspecified[m]	17	8	140	70	24	12	70	157
Hemlock, Douglas fir, cedar[n]	4	2	90	45	5	2		
Ponderosa pine[o]	12	6	195	98	14	7		

[a] Factors expressed as weight of pollutant emitted per weight of refuse material burned.

[b] Particulate matter from most agricultural refuse burning has been found to be in the submicrometer size range. (Darley, April 1974.)

[c] Emission factors: Darley, April 1974 and Darley, June 1975; fuel loading factors: California Air Resources Board, June 1975.

[d] For these refuse materials, no significant difference exists between emissions resulting from headfiring or backfiring.

[e] These factors represent emissions under typical high moisture conditions. If ferns are dried to less than 15 percent moisture, particulate emissions will be reduced by 30 percent, CO emission by 23 percent, and HC by 74 percent.

[f] When pineapple is allowed to dry to less than 20 percent moisture, as it usually is, the firing technique is not important. When headfired above 20 percent moisture, particulate emission will increase to 23 lb/ton (11.5 kg/MT) and HC will increase to 12 lb/ton (6 kg/MT). (Darley, August 1974.)

[g] This factor is for dry (15 percent moisture) rice straw. If rice straw is burned at higher moisture levels, particulate emission will increase to 29 lb/ton (14.5 kg/MT), CO emission to 161 lb/ton (80.5 kg/MT), and HC emission to 21 lb/ton (10.5 kg/MT).

[h] See Section 6.12 for discussion of sugar cane burning. The following fuel loading factors are to be used in the corresponding states: Louisiana, 3-5 ton/acre (8-13.6 MT/hectare); Florida, 4-7 ton/acre (11-19 MT/hectare); Hawaii, 11-17 ton/acre (30-46 MT/hectare). For other areas, values generally increase with length of growing season. Use the larger end of the emission factor range for lower loading factors. (Southerland and McBath, January 1978.)

[i] See accompanying text for definition of headfiring.

[j] See accompanying text for definition of backfiring. This category, for emission estimation purposes, includes another technique used occasionally for limiting emissions, called into-the-wind striplighting, which involves lighting fields in strips into the wind at 100-200 m (300-600 ft) intervals.

[k] Orchard prunings are usually burned in piles. No significant difference in emission results from burning a "cold pile" as opposed to using a roll-on technique, where prunings are bulldozed onto a bed of embers from a preceding fire.

[l] If orchard removal is the purpose of a burn, 30 ton/acre (66 MT/hectare) of waste will be produced.

[m] Yamate et. al, June 1975. Nitrogen oxide emissions estimate at 4 lb/ton (2 kg/MT).

[n] Fritschen et. al., 1970.

[o] Sandberg, et.al., 1975.

and Hawaii. As a result, these factors are used most appropriately for crops grown in these areas; residue and emission factors may vary among geographic regions and thus necessitate some need to assess the accuracy of these numbers outside of these areas. The Air Resources Board in California is currently using residue and emission factors that differ somewhat from the AP-42 factors in calculating emissions from agricultural burning in California. Other limitations of the use of AP-42 emission factors to describe agricultural burning emissions and relevant emission factors from other information sources are presented in Appendix C.

SECTION 5.0

IMPACTS OF AGRICULTURAL BURNING

The primary reason for burning grass and rice fields is to control disease. Other benefits include:

- inexpensive residue removal,
- weed control,
- stimulation of seed yeild,
- insect and rodent control,
- reduced pesticide requirements,
- quicker return of minerals to the soil,
- easier crop establishment,
- increased fertilizer efficiency, and
- reduced fire hazard.[15,22]

Sugar cane is burned prior to harvest rather than after. The benefits of burning sugar cane include:

- reduction in the volume of material that must be handled,
- control over insect pests,
- easier processing at the factory and more productive cane.[23]

Primary concerns about the impacts of open field agricultural burning center on the potential health effects from exposure to smoke and on the reduced visiblity effects that result from aerosols in the smoke. Section 5.0 is devoted to a discussion of these concerns.

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[22] Oregon Agricultural Experiment Station. 1977. Special Report 476: Field Burning in Oregon.

[23] Sloane, G.E. and L.J. Rhodes. 1972. A Comparison of the Processing of Burned and Unburned Sugarcane. Experiment Station, Hawaiian Sugar Planter's Association. Hawaiian Planter's Record, Volume 58, No. 14, 1972. 10 pp.

5.1 POTENTIAL HEALTH EFFECTS

The magnitude of health effects from any air pollutant depends upon the degree of human exposure to the pollutant and the toxicity of the pollutant. Exposure may be estimated using ambient air monitoring data or using dispersion and population models. Toxicity may be measured or estimated using laboratory or epidemiological studies. Combining exposure and toxicity information yields an estimate of health effects. Health effects may also be estimated more directly by using properly designed epidemiological studies.

Evidence presented in available literature suggests several tentative conclusions about potential health effects from agricultural burning smoke. However, the evidence is incomplete and generally only suggestive of certain conclusions. A fairly impressive chain of circumstantial evidence supports an inference of adverse health effects to sensitive persons:

1. Smoke from the burning of many types of organic substances is known to contain toxic and carcinogenic compounds.
2. Concentrated smoke under various circumstances can cause death or serious illness.
3. Any smoke, in high enough concentrations, can be irritating to most people.

These facts, taken together, create a strong presumption that smoke from agricultural burning can be detrimental to some of the people who may inhale it.

There also is direct evidence as perceived by the public that agricultural burning smoke may be significantly harmful or at least irritating. Many people exposed to smoke from field burning are convinced that is causes them respiratory irritation and distress, eye irritation, and, perhaps, acute or chronic illness. In the Willamette Valley, telephoned complaints of this sort clearly mount up on days when smoke

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24. Field Burning in the Willamette Valley: 1977-1978. Volume 10. State of Oregon Department of Environmental Quality, Air Quality Division.

from burning grass is prevalent.[24] Scientific studies neither support no refute the public's perceptions and fears.

Figure 1 in Section 4.0 shows standard metropolitan statistical areas where agricultural burning is prevalent and large numbers of people are potentially exposed to smoke. Highly populated western valleys are particularly susceptible because they tend to trap air, and thus smoke, increasing the probability and magnitude of exposure. One researcher estimated that up to 300,000 people or more might be exposed on a given day in Oregon's Willamette Valley.[25] Researchers have measured emissions of mutagens, pesticides, and toxic compounds such as benzo(a)pyrene, cadmium, nickel, and beryllium in agricultural burning smoke.[15,26]

However, evidence also suggests that the health problem may be insignificant. In no area of the country where agricultural burning is practiced have ambient levels of criteria pollutants been measured at levels violating the primary national ambient air quality standards.[15,27,28] The mutagenic potency measured in ambient concentrations of rice smoke was judged by researchers to be relatively low.[15] Researchers considered emissions of pesticides to be insignificant. Such judgments concerning the safety of the emission levels of toxic compounds and pesticides are not conclusive and require more rigorous study.

It is clear from the preceding sections of this report that agricultural burning is isolated into a set of regionally distinct

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25. Young, W.H. Memorandum: EQC Meeting Information Report: Status of Research on the Public Health Effects of Field Burning Smoke. Agenda Item No. 6. October 19, 1979.

26. Darley, E.F. and Lerman, S.L. Air Pollutant Emissions from Burning Sugar Cane and Pineapple Residues from Hawaii. EPA-450/3-75-071. U.S. Environmental Protection Agency. July 1975.

27. Field Burning: A Review of Air Quality in Oregon's Willamette Valley. State of Oregon Department of Environmental Quality, Air Quality Division. January 1980.

28. How, K. Summary of Controlled Pre-Harvest Burning of Sugar Cane Fields in Hawaii. Hawaiian Sugar Planter's Association.

phenomena. Different crops are burned using different methods in different areas. Region, crop, and burning method differences tend to govern the focus of studies relating to health effects. Most studies have focused on problems specific to localized areas since different crops might yield different smoke constituents, different climatological conditions yield different exposure patterns; and different burning practices yield different smoke concentrations and smoke dispersion patterns. Larger studies encompassing many crops, burning practices, or regions usually have addressed these differences in their results. Future research likely will be influenced by these parameters.

There are several problems inherent to measuring the health effects of agricultural burning that increase the difficulty of obtaining precise and accurate data. Detecting particulate smoke intrusions using 24-hour total suspended particulate measurements is difficult because of small particle sizes, and because intrusions are generally localized and of short duration. Further, particles tend to be submicron in size and thus are not readily detectable by monitoring equipment.[29] Epidemiological studies are confounded by the typical problems associated with selecting a test population and establishing a control group. Epidemiological studies of agricultural burning health effects are complicated even further by unique problems. For instance, agricultural burning is a controversial issue in some localities, particularly in Oregon. The distinct visibility of the smoke tends to bias observations of smoke intrusions. For example, people may envision worse potential health effects than they would if the smoke were invisible. Control groups are particularly difficult to establish for long-term studies because smoke management programs significantly alter the geographic dispersion of the smoke from year to year.[30]

The following sections describe the available information relating to exposure and health effects from exposure to agricultural burning

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29. 1979 Annual Report to the Legislative Committee Economic Development. Volume 16. State of Oregon Department of Environmental Quality, Air Quality Division. January 1980. 67 pp.

30. O'Connell, S. Design Considerations in Planning a Health Effects Study of Field Burning. October 6, 1978.

smoke. Information is given for grass burning in Oregon, sugar cane burning in Hawaii, rice burning, unspecified crop burning, and the Monsanto assessment which estimated exposure on a national scale. Each section addresses information, where available, relating to exposure, toxicity, and epidemiology.

5.1.1 Grass Burning in Oregon

All of the health impact studies relating to smoke intrusions from grass burning have been performed in the Willamette Valley of Oregon, which is particularly susceptible to air pollution problems. Nearly 300,000 acres of grass are grown in or near the valley, which is restricted in ventilation by topography, temperature inversions, and atmospheric stagnation. The prevailing winds are northerly, and they often result in accumulation of smoke in the southern, urban part of the valley.[31] The burning season lasts from late July through September. High pressure systems during this period often result either in temperature inversions, which limit vertical mixing, or in high temperatures which, though they increase vertical mixing, also increase unwanted fire hazards.[24] Oregon Department of Environmental Quality (ODEQ) smoke management plans have been developed that allow burning to occur only on days when conditions will minimize smoke intrusions into populated areas.

Episodes of grass burning air pollution tend to occur as day-long intrusions of smoke. There is no evidence of carryover of concentrations from one day to the next.[27] Worst-case 24-hour total suspended particulates (TSP) ambient air concentrations in the Willamette Valley have been measured at 66 $\mu g/m^3$; the National Ambient Air Quality 24-hour TSP primary standard is 260 $\mu g/m^3$.[15] The annual average TSP concentration in the Willamette Valley is less than 2 $\mu g/m^3$.[27] The National Ambient Air Quality annual TSP primary standard is 75 $\mu g/m^3$.

According to the ODEQ, measurements of peak TSP concentrations occurred during a period when 76,000 people were potentially exposed.[27]

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[31] Chilcote, D.O. Grass Seed Field Burning: Air Quality Aspects. In: Proceedings of the Annual Meeting of the Society of American Soil Conservationists. August 1976. pp. 124-125.

Estimates of maximum potential exposure to smoke from open field burning suggest that up to 300,000 or more persons may be exposed on a given day.[25]

Grass burning TSP emissions consist primarily of fine particulates; approximately 75 to 95 percent by weight are less than 2.2 microns; the median mass diameter is approximately 0.5 microns. The latter size is within the range of maximum alveolar (lung) deposition.[25] One report postulated that particulates may participate in "synergistic" reactions with emissions from other sources such as furnaces, fireplaces, stoves, backyard burning, industrial and transportation sources, and forestry practices.[32] No specific impacts were suggested.

Samples of ambient levels of grass field burning smoke particulates were collected from Eugene and Springfield, Oregon, on days representing both intrusion and nonintrusion conditions. Results from these tests indicated little, if any, mutagenic activity at the doses tested. These findings were described as preliminary.[33]

Each summer and fall, complaints of poor visibility, eye irritation, and aggravation of asthsma and illness are registered and attributed to open field burning practices in the Willamette Valley. It is not clear whether all of these complaints are directly linked to grass burning smoke.[29] However, during day-length grass burning smoke intrusions, the number of complaints increases markedly; on one intrusion day in 1977, the Oregon Department of Environmental Quality received 184 complaints attributed to the smoke intrusion.[23]

An analysis of lung function data collected during a 5-year breathmobile program indicated that residents of the more polluted middle region of the Willamette Valley had better respiratory health than residents tested from less polluted areas of the State. The ODEQ emphasized that these results are subject to valid criticism and should not be considered as evidence that the health risks from long-term

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32. The Practice of Field Burning. In: Agricultural Field Burning in the Willamette Valley. Air Resources Center, Oregon State University. January 1969. pp. 8.

33. Terraglio, F.P. Memorandum: Field and Slash Burning Study. November 22, 1978.

exposures to field burning smoke are negligible or nonexistent.[34] An analysis of 1978 and 1979 hospital admission data from Lebanon, Oregon, revealed no statistical evidence of any effect of smoke intrusions upon the frequency of hospital in-patient admissions.[35]

Ozone levels during smoke intrusions have not been observed to increase although photochemically reactive hydrocarbons are present, as evidenced by the emission factors for hydrocarbons given in Chapter 2 of this report.[27] Polynuclear organic material (POM), suspected to include carcinogens, has been measured in smoke samples taken directly from the field and in ambient air downwind. Ambient POM levels downwind were found to be "relatively low or below detectable limits."[25] Although their description implied a judgement that the POM levels were safe, the researchers did not explicitly address the issue of safety.

5.1.2 Sugar Cane Burning in Hawaii

Emissions from sugar cane burning in Hawaii are dispersed mostly over the ocean, since sugar plantations are located on the four widely separated islands distributed along a straight line about 300 miles long and oriented in a NW-SE direction perpendicular to the direction of the prevailing tradewinds (ENE). Field burning is allowed by the State to occur only when conditions are favorable for rapid dissipation of the smoke in the atmosphere.[28]

According to the Hawaii Sugar Planter's Association, 10 years of ambient air monitoring in Hawaii:

> "demonstrated that cane burning contributes an insignificant amount to the particulate loading in the atmosphere. In 1978, Honolulu was the only major city in the U.S. where ambient air concentrations of all 5 major criteria pollutants were below NAAQS. Other areas in Hawaii surrounded by cane fields have better air quality than Honolulu."[28]

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[34] Srivastava, N. and Calvin, L.D. A Study bof Pulmonary Lung Function as Measured under the Oregon Lung Associations Christmas Seal Breathmobile Program, 1972-1977.

[35] Hanlen, R.C. and Calvin, L.D. Preliminary Health Effects Study: Analysis of Hospital Admissions Data. Department of Statistics, Oregon State University. February 1981.

According to one EPA report, sugar cane burning emissions in Hawaii contain hydrocarbons, particulate matter, carbon monoxide, benzo(a)pyrene, beryllium, cadmium, and nickel (see Table 7).[26] Ninety percent of the particles from sugar cane leaf trash were found to be less than 0.5 microns in diameter (as previously noted, particle sizes smaller than 1 micron are more likely than larger particles to lodge deeper in the lung.

5.1.3 Rice Burning

One study surveyed existing data to determine whether insecticides, herbicides, and fungicides are present in rice straw residue.[15] Results indicated that contamination from persistent chemicals is unlikely since these chemicals are found only in very small concentrations in the residue. Residue contamination from less persistent chemicals was judged more likely, but "not cause for alarm" since environmental and metabolic dissipation processes would mitigate against substantial residues in the straws at harvest.

A mutagenicity study of rice straw smoke condensate (collected smoke particles) using AMES assay methods indicated that the basic pH portion of the condensate was the most mutagenic, followed by the neutral pH, the amphoterics, and the weak acids. The researchers judged, in an admittedly rough comparison, that rice straw smoke collected one mile from a burning rice field has approximately the same mutagenic potency as an air sample from a high-density traffic area in downtown Los Angeles; or, if breathed for 21 days, the smoke sample would have the same mutagenic response as the cigarette smoke condensate from one cigarette.[15]

5.1.4 Characterization of Pollutants from Unspecified Crops

The characteristics of particulates in smoke from agricultural burning were described in two reports.[3,36] Neither report specified the type of crop. Particulates were characterized as tending to be submicron in size, meaning that there is a high potential for significant lung accumulation. Most of the submicron particles appeared to the researchers

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36. Carroll, J.J. Determination of Temperature, Winds, and Particulate Concentrations in Connection with Open Field Burning. California Air Resources Board. November 1973.

Table 7. EMISSION FACTORS OF TOXIC CHEMICALS IN EMISSIONS FROM BURNING SUGAR CANE IN HAWAII[26]

	Benzo(a) Pyrene (μg/g particulates)	Beryllium (pg/m^3)	Cadmium (pg/m^3)	Nickel (pg/m^3)
Whole Cane	73.1	0.22	1.96	1.92
Leaf trash	79.0	0.32	2.03	1.02

to be "tarry" or liquid aerosol hydrocarbons, suggesting that they may be carcinogenic or reactive with other chemicals in the air. Many of the hydrocarbons were at least partially oxidized, indicating to the researchers that a number of toxic or photochemically reactive components, such as olefins, aldehydes, and ketones, may be present. Data on aged plumes indicated a size shift to smaller sizes among the liquid particles, suggesting a slow evaporation with time.

5.1.5 The Monsanto "State-of-the-Art" Source Assessment

Under contract to the U.S. EPA, Monsanto Research Corporation estimated ambient air concentrations and population exposures to high pollutant concentrations from a typical agricultural open field burn.[3] The results of their calculations are shown in Tables 8 and 9. Table 8 shows maximum and time-averaged-maximum ground level pollutant concentrations, and compares them to health-related standards in a ratio termed "source severity." Note that hydrocarbons are the only pollutant that approach the health standard. Table 9 shows best and worst case estimates for area and population exposed to hydrocarbons and benzo(a)pyrene for ambient concentrations equivalent to source severities ≥1.0 and ≥ 0.1. In the worst case scenario, 800 persons would be exposed to hydrocarbons, and 200 persons would be exposed to benzo(a)pyrene at source severity levels ≥ 0.1. Eighty persons would be exposed to hydrocarbons at source severity levels ≥1.0.

The study assumes smoke emissions from an average burn on an average-sized farm which is burning an unspecified crop in an area of the U.S. where there exists average meteorological conditions and an average burning-area population density. These results are nonspecific, highly aggregated, and are subject to large uncertainty due to the lack of input data and the use of assumptions concerning emissions, burning parameters, dispersion, and population distribution. Monsanto did not estimate the degree of uncertainty in the results.

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37. O'Connell, Sean K. 1981. 1980 Annual Report ofn Field Burning. Presented to the Joint Legislative Committee on Trade and Economic Development. Department of Environmental Quality, Oregon. 8 pp.

Table 8. MAXIMUM GROUND LEVEL CONCENTRATION AND SEVERITY FACTOR OF DIFFERENT EMISSIONS[a],3

Emission	Maximum Ground Level Concentration (g/m^3) Range	Maximum Ground Level Concentration (g/m^3) Average	Time-Averaged Maximum Ground Level Concentration (g/m^3)	Threshold Limit Value[l] (g/m^3)	Primary Ambient Air Standard (g/m^3)	Source Severity[n]
Particulates	5×10^{-5} - 5×10^{-3}	7×10^{-4}	2×10^{-5}[b]	1.0×10^{-2}	2.6×10^{-4}[b]	0.08
Hydrocarbons	6×10^{-5} - 6×10^{-3}	8×10^{-4}	2×10^{-4}[c]	6.72×10^{-2}	1.6×10^{-4}[c]	1
CO	3×10^{-4} - 3×10^{-2}	4×10^{-3}	2×10^{-3}[d]	5.5×10^{-2}	4.0×10^{-2}[d]	0.06
NO_x	6×10^{-6} - 6×10^{-4}	8×10^{-5}	2×10^{-9}[e]	9.0×10^{-3}	1.0×10^{-4}[e]	0.00007
POM B(a)P	2×10^{-9} - 2 x $^{10-7}$	2×10^{-8}	7×10^{-10}[b]	1.0×10^{-6}	NA[f]	0.2
Trace metal elements						
Ni	8×10^{-16} - 8×10^{-14}	1×10^{-14}	3×10^{-16}	7×10^{-6}[g]	NA	1×10^{-8}
Cr	2×10^{-16} - 2×10^{-14}	4×10^{-15}	1×10^{-16}	5×10^{-4}[h]	NA	6×10^{-11}
Be	2×10^{-16} - 2×10^{-14}	3×10^{-15}	7×10^{-17}	2×10^{-4}[i]	NA	1×10^{-8}
Cd	1×10^{-15} - 1×10^{-13}	2×10^{-14}	5×10^{-16}	2×10^{-4}[j]	NA	1×10^{-10}
Cu	4×10^{-15} - 4×10^{-13}	6×10^{-14}	2×10^{-15}	1×10^{-3}[k]	NA	5×10^{-10}

[a] Calculations are based on assumed emission factors.

[b] 24-hour average.

[c] 3-hour average.

[d] 1-hour average.

[e] Annual average.

[g] TLV for nickel carbonyl.

[h] TLV for soluble chromic, chromous salts.

[i] TLV for elemental beryllium.

[j] TLV for cadmium metal oxides.

[k] TLV for copper dusts and mists.

[l] Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment.

[m] National Primary and Secondary Ambient Air Quality Standards. U.S. Environmental Protection Agency, Federal Register, 36, April 1977 (not promulgated for hydrocarbons).

[n] Time-averaged maximum ground level concentration divided by the primary ambient air quality standard for criteria pollutants or a "corrected" threshold limit value (TLV. 8/24.1/100 for non-criteria pollutants.

Table 9. AREA AND POPULATION EXPOSED TO POLLUTANTS FOR WHICH SOURCE SEVERITY ≥ 1.0 AND SOURCE SEVERITY ≥ 0.1[a,3]

			Exposed population, persons					
	Affected area, km^2		Best case		Worst case		Average	
Pollutant	Source Severity ≥ 1	Source Severity ≥ 0.1	Source Severity ≥ 1	Source Severity ≥ 0.1	Source Severity ≥ 1	Source Severity ≥ 0.1	Source Severity ≥ 1	Source Severity ≥ 0.1
Hydrocarbons	0.3	3	0.5	5	80	800	8	80
POM B(a)P	NA[b]	0.8	NA	1	NA	200	NA	20

[a] Based on assumed emission factors.

[b] Not applicable.

5.2 NONHEALTH RELATED CONCERNS

In addition to the potential health risks of smoke from agricultural burning, major reported public concerns include nuisance effect, contribution to deterioration of air quality, visibility loss, and hazard to vehicular and air traffic. Other important concerns included soiling damage of property and loss of property value.

Loss of visibility, which is caused primarily by the presence of large amounts of aerosols in the smoke, results in hazards to vehicular and air traffic.[32] This is a problem especially where agricultural burning is conducted along highways and airport landing strips.

Most available information relating to public concern about agricultural burning concerns Oregon. Table 10 shows the number of complaints received by the ODEQ from 1973 to 1980 and the corresponding number of acres burned. The high number of complaints in 1980 has been reported to be attributable in part to the increase in acres burned and in part to the coincidence of favorable burning opportunities on weekends when more people are typically out-of-doors.[37]

Table 10. NUMBER OF COMPLAINTS, OREGON[29]

	1973	1974	1975	1976	1977	1978	1979	1980
Number of Complaints	588	1,196	761	318	746	552	429	1,183
Acres Burned	264,000	282,741	186,260	165,712	171,500	153,890	153,043	212,126

Visibility loss was the most mentioned complaint during the summer of 1969 in Oregon,[38] when over 5,000 complaints about agricultural burning were received. Poor visibility has been criticized in Oregon for its possible detrimental effect on tourism due to the loss of aesthetically desirable views.[39] However, a study of tourist behavior

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38. Oregon State University. Agricultural Experiment Station. 1973. Economic Characteristics of Farms Producing Grass Seed in Oregon's Willamette Valley. Circular of Information 643. 82 pp.

39. Conklin, Frank S., and R. Carlyle Bradshaw. 1971. Farmer Alternatives to Open Field Burning: An Economic Appraisal. Special Report 336. Agricultural Experiment Station, Oregon State University, Corvallis, Oregon. 15 pp.

in 1971 has shown that poor visibility appears to affect tourism relatively little.[40]

In California, one of the concerns about agricultural burning is its impact on air quality. One report concluded that the extent of this concern, which is large, "appears to be somewhat out of proportion to the actual effect of open field burning or statewide air quality."[15] This same report does note that visibility and aesthetic impacts may be quite large at times.[15]

In Washington, complaints over a 30-day period in 1981 were noted mostly for visibility, with about 2 to 3 percent for odor. One official in Arkansas noted that his state sporadically receives batches of complaints about agricultural burning. In Texas, many complaints concerning deposition of ash over clothes and in swimming pools were received when sugar cane and, hence, sugar cane burning, were introduced into the Rio Grande Valley.

Personal communications with officials in some states where agricultural burning is practiced noted few or no complaints about the smoke. Reasons for the lack of complaints appear to be the expectations of the people in the areas where agricultural burning is practiced - they are accustomed to it, and, more likely than not, burn agricultural residues themselves.

Areas recommended in the literature for research concerning non-health related concerns include: (1) the evaluation of tourist activity visibility hazards for transporation, soiling effects, and the aesthetic value of improved visibility[25] in the Willamette Valley, and (2) the evaluation of the economic gains and losses associated with driving hazards and soiling and nuisance effects from air pollution.[40]

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40. Conklin, Frank S., and R. Carlyle Bradshaw. 1979. An Evaluation of Expected Private Losses from Selected Public Policies for Reducing Open Field Burning, Willamette Valley, Oregon. Agricultural Experiment Station, Oregon State University, Corvallis, Oregon. Circular of Information 675. 78 pp.

SECTION 6.0

POLICIES AND ALTERNATIVES TO CONTROL AGRICULTURAL BURNING

In response to the various concerns about agricultural burning, several policies and alternative measures to control the practice have been explored and, in some instances, implemented. Most have been researched and implemented in California and Oregon. Other states that were found to have an active interest in controlling the practice include Hawaii, Florida, Washington, Idaho, and Texas. The following sections describe the policies considered or implemented and the various alternatives that have been researched for control of agricultural burning.

6.1 REGULATION OF AGRICULTURAL BURNING

There is a wide variation among states in the extent to which agricultural open burning is regulated. About half the states simply exempt agricultural open burning from a general prohibition of open burning. The exemptions usually are conditional upon certain provisions, such as not creating a public nuisance or a hazard to vehicular or air traffic. The other half of the states require the issuance of a permit, authorization or certificate prior to burning. (See Table 11.) The regulations contain a wide range of conditions to be included in the permits, the most common of which, in descending order of frequency, are:

1. Burning only under favorable meteorological conditions. This may refer to favorable conditions for dispersion or to prevailing wind directions away from populated areas, major roadways, and airports. In some instances, burning is allowed only when the wind speed is above or within a certain surface wind speed range.
2. Time of day when burning is allowed. Most often burning is required to take place after sunrise and before sunset.

Table 11. STATE REGULATION OF AGRICULTURAL BURNING

Region/State	Permit, Approval, Certificate, etc., Required Prior to Burning No	Yes	Degree of Restrictions or Conditions Under Which Agricultural Burning May Take Place
Northeast			
Connecticut		x	M
Delaware		x	M
Maine		x	M
Maryland		x[a]	M
Massachusetts		x	LM
New Hampshire	x		L
New Jersey		x	L
New York			
Pennsylvania[b]			
Rhode Island[c]			
Vermont	x		L
West Virginia	x		LM
Midwest			
Illinois		x[d]	M
Indiana	x		LM
Iowa			
Kansas	x[e]		MH
Michigan			
Minnesota		x	M
Missouri		x[f]	LM
Nebraska		x	L
North Dakota	x		M
Ohio		x[g]	LM
South Dakota	x		M
Wisconsin	x		L

Table 11. STATE REGULATION OF AGRICULTURAL BURNING (Continued)

Region/State	Permit, Approval, Certificate, etc., Required Prior to Burning		Degree of Restrictions or Conditions Under Which Agricultural Burning May Take Place
	No	Yes	
South			
Alabama	x		L
Arkansas		x	L
Florida		x	LM
Georgia	x		L
Kentucky			
Louisiana	x		L
Mississippi		x	L
North Carolina		x[h]	L
Oklahoma	x		M
South Carolina	x		L
Tennessee	x	x[i]	LM
Texas	x[j]		MH
Virginia	x		L
West			
Alaska		x[k]	L
Arizona		x	
California		x	H
Colorado		x	M
Hawaii		x	MH
Idaho		x	LM
Montana		x[l]	LM
Nevada	x		L
New Mexico	x		
Oregon		x	H

Table 11. STATE REGULATION OF AGRICULTURAL BURNING (Concluded)

Region/State	Permit, Approval, Certificate, etc., Required Prior to Burning		Degree of Restrictions or Conditions Under Which Agricultural Burning May Take Place
	No	Yes	
Utah		x	L
Washington		x	MH
Wyoming	x[m]		L

Key: H = High

MH = Medium to High

M = Medium

LM = Low to Medium

L = Low

FOOTNOTES FOR TABLE 11

[a] Applies only to the following areas in Maryland: Baltimore Metropolitan, Washington Metropolitan, Southern, and Eastern Shore. Excludes Central and Western areas.

[b] Section 4004.1 of Pennsylvania's Air Pollution Control Act states: "The Environmental Quality Board shall not have the power nor the authority to adopt rules and regulations relating to air contaminants and air pollution arising from the production of agricultural commodities in their unmanufactured state but shall not include the use of materials produced or manufactured off the premises of the farm operation."

[c] Air Pollution Control Regulation No. 4, Open Fires, Section 4.2 prohibits all open fires with Section 4.3(a) exempting burning for weed abatement or pest control after receiving the approval of the Director.

[d] Only for agricultural waste caused by a disaster in an officially declared disaster area. Rule 504(a)(6).

[e] May be specifically prohibited by Department of Health, its officially designated representatives or other authorities having local jurisdiction in the matter, where it is demonstrated to be in the best interests of public health and welfare.

[f] Applies only to the St. Louis Metropolitan area.

[g] In "restricted areas." Areas within the boundaries of any Municipal Corporation plus a zone extending 1,000 feet beyond the boundary if population is 1,000 to 10,000 persons and a zone extending 1 mile beyond the boundary if the population is of 10,000 persons or more.

[h] Permit is required for any fire within 500 feet of a "protected" woodland in a "high hazard" county and within 500 feet of a "protected" woodland in a "non-high hazard" county between the hours of midnight and 4:00 p.m.

[i] Only for trees, limbs, brush, lumber, excelsior, dunnage and other items of comparable combustion characteristics for repetitive burning at the same site.

[j] Only for those crop management purposes not specifically governed by orders issued pursuant to a written grant of authority from the Texas Air Control Board or Executive Director.

[k] Applies, in part, to the controlled burning for the management of "vegetative cover."

[l] Only applies for 1,000 acres or more.

[m] Permitted when it can be shown that such burning is necessary and that no fire hazard or public nuisance will occur.

3. Distance from occupied buildings, major roadways, and airports. Many states require that the burning occur a specified number of feet from these and other areas.
4. Contribution to air pollution. Often open burning is allowed if it does not create an air pollution hazard or cause or contribute to the violation of an ambient air quality standard. In many instances, agricultural open burning is prohibited during an air pollution episode.
5. Condition of the material to be burned. Many states restrict the types of materials which can be burned with the agricultural residues and require that efforts be made to minimize the amount of dirt in the residues. Some states require that the residues be stacked or dried in a certain way prior to their being burned.

In addition, many state regulations allow agricultural open burning provided no alternative method of disposal is economically or technically available.

In theory, one would expect the degree of regulation of agricultural burning to vary directly with the extent of the practice. However, upon examination, this relationship does not hold. This is especially evident for the southern region where the most agricultural burning takes place in generally the least regulated legislative environment.

Table 12 shows the distribution of the degree of regulation within each region. This table summarizes the information in Table 11; thus, for example, in the Northeast, 4, 2, and 3 states were considered to have, respectively, medium, low to medium, and low amount of restrictions on agricultural burning.

Three major factors have been identified that appear to affect the extent to which a state regulates agricultural burning:

1. The proximity of agricultural burning to population centers;
2. Prevailing meteorological conditions; and
3. The importance of agriculture to the state.

As population centers and agricultural burning come closer to one another, pressure to control the practice generally grows. This is especially evident in Oregon and California as well as in areas such as the Rio Grande Valley of Texas, and Palm Beach County, Florida.

Table 12. DEGREE OF AGRICULTURAL BURNING REGULATION, BY REGION

Degree of Regulation	Region			
	Northeast[a]	Midwest	South	West
H				2
MH		1	1	2
M	4	4	1	1
LM	2	3	2	2
L	3	2	8	4

[a] Pennsylvania prohibits air regulations affecting agricultural activities.

KEY:
H = High
MH = Medium to High
M = Medium
LM = Low to Medium
L = Low

Greater efforts to control the practice also appear in those areas subject to adverse meteorological conditions during the burning season, such as in the Willamette Valley of Oregon. Where prevailing weather conditions are typically favorable to dispersion, such as in the lower midwest, fewer restrictions are found necessary.

The importance of agriculture to a state generally affects the level of regulation inversely - the more important agriculture is to a state, the less likely the state will have restrictive regulations. This appears to be the major factor for the low level of regulation and management of agricultural burning in the southern region.

In California, which has a well-developed smoke management plan and where agriculture is the largest industry, the air pollution control law for agricultural burning states: "It is the intent of the Legislature... that agricultural burning be reasonably regulated and not be prohibited."[41] Several states have implemented various types of general "right-to-farm" legislation, as shown in Table 13.

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41. California Air Pollution Control Laws. Article 3. Meteorological Criteria for Regulating Agricultural Burning.

Table 13. STATES WITH RIGHT-TO-FARM LAWS[42,a]

Laws Protecting Against Local Government Regulations

Alabama (1980)
Delaware (1980)
Illinois[b] (1979)
Kentucky (1980)
Louisiana (1978)
Maryland[b] (1977)
Minnesota (Twin Cities)[b] (1980)
New York[b] (1971)
North Carolina (1979)
Oregon (1973)
Tennessee (1979)
Virginia[b] (1977)

Laws Protecting Against State Regulations

Tennessee (1979)
Oregon[b] (1973)

Laws Protecting Against Private Nuisance Lawsuits

Alabama (1980)
Delaware (1980)
Florida (1979)
Georgia (1980)
Kentucky (1980)
Louisiana (1978)
Mississippi (1980)
North Carolina (1979)
Oklahoma (1980)
Tennessee (1979)
Washington (1979)

[a] Some states provide more than one form of protection.

[b] The statute applies only in agricultural districts or, in the case of Oregon, in exclusive farm use zones.

In addition to the states identified in the above table, Pennsylvania legislation prohibits the Department of Environmental Quality from regulating air pollutants from agricultural burning,[43] and Idaho has recently passed a bill which makes finding smoke from agricultural burning a "nuisance" under the law more difficult.[44]

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42. Coughlin, Robert E., John C. Keene, J. Dixon Esseks, William Tower, and Lisa Rosenburg. 19 . The Protection of Farmland: A Reference Guidebook for State and Local Governments. A Report to the National Agricultural Lands Study from the Regional Science Research Institute, Amherst, Massachusetts. U.S. Government Printing Office. 284 pp.

43. Pennsylvania Air Pollution Act. Section 4004.1 Agricultural Regulations Prohibited.

44. Intermountain Grass Growers Association. Swather, Nov.-Dec. 1981.

6.2 SMOKE MANAGEMENT OF AGRICULTURAL BURNING

A few states, such as California, Hawaii, Oregon, and Washington, have implemented smoke management programs designed to provide direct control over when, where, and how much agricultural burning takes place. Of these states, California and Oregon have the most detailed programs.

The objective of smoke management usually is to minimize the emissions from open burning or to minimize the impact of smoke on populations or both. Oregon defines smoke management as:

> "... the daily control of the conducting of open field burning to such times and places and in such amounts so as to provide for the escape of smoke and particulate matter therefrom into the atmosphere with minimal intrusion into cities and minimal impact on public health and in such a manner that under existing meteorological conditions a maximum number of acres registered can be burned in a minimum number of days without substantial impairment of air quality."[45]

The specific steps employed by a state to achieve these objectives constitute the state's "smoke management plan." Each of the above four states has different steps, though each usually has some of the following characteristics:

1. Registration of acres which a farmer or grower desires to burn in the coming year.
2. Designation of burn or no-burn days based on a number of specific meteorological parameters.
3. Allocation procedure to determine how many and which acres will be burned on a given day.
4. The specific firing technique to be used.

6.2.1 Fuel Management

Several fuel characteristics have been determined to affect the quantity of pollutants emitted or the potential dispersion of pollutants. The factors include fuel moisture content, fuel loading, amount of green regrowth, and distribution of fuel in the field (piling of the residue). Of these factors, fuel moisture content is the most important. The higher the fuel moisture content, the poorer the combustion, and the greater the release of particulates, hydrocarbons, and carbon monoxide. Fuel moisture content has been incorporated as part of the smoke management plans of both California and Oregon.[46] Fuel loading affects the amount of pollutants in that the greater the amount of residue, the more uniform the burn. Quantities of emissions generated vary directly with the amount of green regrowth after harvest. Studies show that the method of piling residue in the field affects the amount of emissions. Generally, residues that are spread evenly or are "fluffed" prior to burning generate less emissions than those left in windrows or piled by allowing more complete oxidation to occur. In Oregon, a technique known as "fluffing" has been shown to have considerable value in enhancing the plume rise characteristics of a burn and reducing the associated low level of smoke.[37]

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[45] Oregon Revised Statutes, 468.453(1).

6.2.2 Firing Techniques

Several firing techniques are available which reduce potential human exposure by reducing emissions or providing better updrafts. The major firing techniques used are:

(1) Headfiring: a single flame front advances with the surface wind direction.

(2) Backfiring: a single flame front advances into the surface wind direction.

(3) Into-the-Wind Strip Lighting: backfiring with additional flame fronts advancing into the surface wind direction.

(4) Perimeter Lighting: all sides of the field are ignited.

Headfiring is the traditional firing technique. It generally produces the most emissions, a rapid burn, and good plume loft.

Backfiring was the first alternative burning technique to be studied. Backfiring has been shown to substantially reduce emissions in comparison to headfiring, and produces the lowest amount of emission among these four burning techniques. However, surface smoke impact can be greater with this firing technique than with the others. In addition, backfiring gives the slowest burn, covering the field up to 20 times slower than headfiring.[47]

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[46] Oregon Field Burning: Smoke Management Program Operational Guidelines. Revised May 26, 1981. 40 pp.

Into-the-wind-stripfiring reduces the burn time associated with backfiring, produces emissions equivalent or greater than backfiring but less than headfiring, and produces a plume loft between that produced by backfiring and headfiring.

Perimeter burning provides maximum plume loft and minimizes the amount of ground level smoke. However, this technique may produce the greatest fire danger.

In addition to these different burning techniques, the effect of alternate year burning is being explored in such states as Oregon and Idaho. Such a burning scheme where straw would be removed in the non-burn year, would reduce emissions by half. The impact of this burning scheme on crop seed yield, pest control, and disease control is still uncertain. In addition, problems associated with straw removal and disposal in the non-burn year remain. (See Section 6.3.3 for further discussion on straw removal and disposal.)

Firing techniques may be specified in smoke management plans. For example, in Oregon, perimeter burning of fields may be required where winds and fire danger are minimal.[29] In California, rice, barley, oat, and wheat straw are required to be burned using into-the-wind stripfiring or backfiring except under a special permit or where crops are determined not to lend themselves to these techniques.[48]

6.2.3 Meteorologically Scheduled Burning

Much research of meteorological conditions favorable for the dispersion of smoke from agricultural open burning has been conducted. The results of the research have been incorporated into smoke management plans, especially for the determination of burn versus no-burn days.

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[47] Miller, George E. et al. 1976. A Program to Minimize the Effects of Agricultural Burning in California. Submitted to Journal of the Air Pollution Control Association, March 1976. 26 pp.

[48] California Air Pollution Rules. Subchapter 2. Agricultural Burning Guidelines. Article 2. Implementation Plan 80150(d)(3).

Even in the states without smoke management plans, presence of favorable meteorological conditions often is a limitation restricting agricultural burning. Among the most important meteorological data monitored are wind direction, wind speed, mixing height, rainfall, relative humidity and absolute humidity.

Wind direction is a primary criterion as it determines the potential incursion of smoke into nearby towns, airports, roadways, etc. Burning usually is prohibited upwind of such areas unless plume loft conditions are favorable enough to allow limited burning without affecting downwind populations or traffic.

Wind speeds at the surface and upper levels are important due to their effects on plume characteristics. Strong surface winds, for example, tend to fracture plumes and create excessive low level smoke concentrations.[29] On the other hand, light surface winds do not provide adequate transport, and, therefore, downward mixing may reintroduce smoke into the lower levels. Experience in Oregon has shown that surface winds less than 10 mph do not inhibit plume rise; surface winds between 10 and 15 mph tend to fracture plumes and hinder plume rise by entrainment of colder ambient air; and wind speeds greater than 15 mph introduce difficulties for fire control and also produce turbulent transport of smoke back to the surface.[47] Incorporation of wind speed data into smoke management plans, and even in some regulations, may consist of specifying a minimum surface wind speed or a wind speed range (i.e., minimum and maximum).

Mixing height, the minimum estimate of atmospheric mixing, provides an estimate of the vertical movement of the plume. Together with wind speed, it defines the atmospheric volume available for smoke dispersal per unit time.[47]

Rainfall, relative humidity, and absolute humidity are monitored due to their effect on the moisture content of the residue. After periods of rainfall, a minimum number of hours or days may be required or the relative humidity may be required to be below a certain level before a field may be burned.

6.3 ALTERNATIVES TO AGRICULTURAL BURNING

Smoke management plans primarily deal with minimizing human exposure by keeping the smoke away from populations. Other efforts have been and are being made for the direct replacement of open burning as an agronomical practice.

Major alternatives to replace agricultural burning considered to date include the mobile field sanitizer, alternative crops, mechanical residue removal, residue incorporation, and alternative residue uses. Several factors are important in considering the viability of these and any other alternatives. First, open field burning provides three services--residue removal, residue disposal, and field sanitation. Therefore, the viability of any single alternative depends in part on its ability to provide these same services and, in part, on the development of other alternatives such that a combination of methods can provide the same services. Second, free adoption of alternative methods by farmers depends on economic competitiveness. Open field burning in almost all cases has shown to be the most cost-effective practice. Third, the alternative must also be agronomically feasible. Any alternative that significantly reduces crop yields is not likely to be accepted by farmers or growers. A brief discussion of each of these alternatives follows.

6.3.1 Mobile Field Sanitizer

When alternatives to agricultural burning were first considered, the mobile field sanitizer received much attention and research effort. Efforts in California and Oregon to develop a successful mobile field sanitizer, however, have failed due largely to its relatively high cost of construction and maintenance and the requirement that all or part of the straw load be removed from the field.[29]

In California, a mobile field sanitizer, developed by Oregon State University, was tested on rice fields during the early 1970s. Results of these tests indicated that while carbon monoxide and hydrocarbon emissions were reduced, particulate emissions were increased over those emissions from open burning. In addition, the mobile field sanitizer was found to be of limited durability, maneuverability and fire control value.[49] Finally, the forward speed of the machine had

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49. Miller, George, E. Jr., and John R. Goss. 1973. Study of Abatement Methods and Meteorological Conditions for Optimum Dispersion of Particulates from Field Burning of Rice Straw. Rice Straw Incinerator Evaluation. California Air Resources Board Project No. 1-102-1. 37 pp.

to be very slow due to large amounts of rice straw and the sheer weight made its use "practically impossible" during much of the normal burning months in California due to poor (e.g., wet, rutted) field conditions.[15] As a result, research was discontinued in California with the approval of all concerned.[15]

In Oregon, research to develop the mobile field sanitizer continued until 1978. A report produced by the FMC Corporation evaluating the progress on the development of a mobile field sanitizer concluded that though

> ... a machine can be made which can effectively accomplish the sanitation function, achievement of significant emission reductions was unlikely. Reductions in costs of construction and machine maintenance did not appear likely in the future and considerable annual subsidy was expected to be necessary to enable growers to realize the same net profit using the sanitizers as they would with open field burning. In addition, none of the machines which had been built to date were considered to have been adequately tested or ready for production.[29]

Based on these conclusions, Oregon elected to discontinue the development and testing of mobile field sanitizers.

In summary, while the mobile field sanitizer appears to have equivalent sanitation capabilities, it remains an uneconomical and impractical alternative to open field burning. Even if an economical and practical mobile field sanitizer were developed, it has been noted that "a time lag of four to five years may be required for their production" and "an additional 5 to 10 years of use assurance to the farmer by pollution control agencies might be required to entice its purchase, assuming that grass growers could internally absorb the sanitizer costs and continue to operate profitably."[39] With research discontinued at this time in California and Oregon, development of a mobile field sanitizer for the time being, is a "moot issue."[40]

6.3.2 Alternative Crops

One alternative to agricultural burning is to replace crops whose residues are typically burned with crops whose residues need not be burned. The feasibility of this alternative depends upon the relative economic and agronomic capabilities of the alternative crop to the current crop. Where crop patterns have developed over time in accordance with agronomic conditions and market demands, there is a limited potential for major crop shifts.

Most research in this area appears to be taking place in Oregon. Experience in the Willamette Valley has shown that alternative crops with the best agronomic viability have not been economically competitive with perennial grass seed production in the Valley.[29] The Oregon Department of Environmental Quality notes that in the Willamette Valley, "the poor quality of soils on much of the Valley floor effectively limits the kinds of crops which can be grown, and the economic risks to the grower of making major cropping changes has been prohibitive"[29] and that at present "there are currently no economical crop substitutes available to grass seed growers in most areas of the Willamette Valley."[29]

Research is continuing in the Willamette Valley on two potential alternative crops, meadowfoam and rapeseed. Meadowfoam has the most potential, especially as a viable option for a large portion of the annual ryegrass acreage. Meadowfoam is well suited to the poor soil conditions in the Valley, its residue easily decomposes on the ground, and it requires essentially the same equipment and cultural practices as grass farming.[29] Rapeseed can be grown on a variety of soils, although it is not tolerant of prolonged wet conditions.[29] Both crops show some economic promise as well.

In California, rice farmers have been reluctant to stop farming rice because of the unsuitability of the high-clay soils for growing other crops.[15] In the Sacramento Valley of California, approximately half the rice acreage can be switched to or related with other crops, although the extent to which this is feasible needs to be determined.[15]

6.3.3. Mechanical Residue Removal

Several mechanical residue removal practices, involving the removal of straw alone or both straw and stubble in grass fields and rice, barely, alfalfa, and other field crops whose residue may be classified as straw and stubble, have been researched. Different harvest and collection methods have been tried, ranging from simply using available forage harvesting equipment to collect harvested rice straw[15] to collection methods geared specifically for residue removal, such as crew-cutting. Crew cutting, which is being studied in Oregon, has been defined as "a technique for removing residual plant materials from the field following harvest by clipping standing plant material at or near ground level and sweeping up and collecting the chaff from the surface."[29]

In general, the research in Oregon has indicated that under some conditions mechanical residue removal provides adequate field sanitation.[29] However, this practice is more expensive than open field burning and is therefore uneconomical, unless a market for the collected straw can be developed to offset the increased costs. (In California, almond and walnut growers are finding collection of almond and walnut trash for use in energy generators to be economical.) In addition, the removal techniques often face practical difficulties of removal due to unfavorable field conditions such as uneven terrain, rutting, and mud. Finally, there is uncertainty as to the continued ecological effects of long-term residue removal in terms of soil nutrition, pest control, and disease control.

For most residues, there is no currently available mechanical residue removal technique that can completely and economically replace open field burning. Research in this area is continuing in both California and Oregon. In California, a three-year program is underway to develop an economical system for collection and handling of rice straw that is feasible for rice farming.[15] In Oregon, research is continuing on the crew-cutter technique.

6.3.4 Soil Incorporation

The potential for the incorporation of crop residues into the soil to replace open field burning is limited primarily by economics, lack of adequate pest and disease control, and decomposition rate. An additional factor may be residue loading, as heavy loadings make incorporation of all of the residue very difficult, possibly resulting in straw being returned to the surface. If straw returns to the surface, difficulties in reestablishment of grass stands during plowing in subsequent years may occur.[50] Finally, farmer attitudes toward changing practices may slow acceptance of this practice and limit its potential to replace burning.

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[50] Chilcote, D.O. and H.W. Youngberg. 1975. Non-burning Techniques of Grass Seed Residue Removal. Agricultural Experiment Station, Oregon State University, Progress Report EXT/ACS 9. 8 pp.

The importance of the above factors in limiting the potential use of soil incorporation varies with the type of crop and the geographic location. For example, rice straw can be returned to the soil in the southern rice belt due to its rapid decomposition there, whereas in California straw decomposition is not as rapid. Even within California, the potential for plowing rice straw back into the ground varies as straw decomposition rates have been found to vary substantially among the soil series on which rice is grown.[15]

Also, in California, research has shown that soil incorporation of residues is a technically acceptable alternative to burning under conditions typical of much of the state's rice acreage. However, it is more expensive than agricultural burning, and, where stem rot disease is a problem, continued plowing under results in substantial yield reductions.[15]

In Oregon, soil incorporation is technically feasible only for the annual ryegrass,[39] (perennial grasses are not cultivated during the life of the stand) although high straw yields, dense clay soils and wet environment are not conducive to straw decomposition.[51] However, it is expensive and does not provide weed control to the same extent as burning.[50] Test results have shown marked reductions in seed yields with this and other nonburning seed bed preparation methods compared with open field burning.[52]

In Nebraska, soil incorporation has become more widely used in the last 10 years or so. Previously, nearly every wheat field was burned after harvest. Now, an estimated 1 in 20 wheat fields is burned. This change in practice has occurred due to the "reeducation"

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51. "Solid Wastes Management." 1971. Reprinted in Environmental Quality in Oregon 1971: A Summary of Current and Future Problems. Advisory Committee on Environmental Science and Technology. 4 pp.

52. Oregon. Agricultural Experiment Station. 1977. Field Burning in Oregon. Special Report 476. 24 pp.

of the farmer concerning the relative desirability of the two practices. Where burning still occurs, it is attributed to reluctance of the long-time farmer to change from the practice he has always used.

In general, soil incorporation as an alternative to agricultural burning appears to be limited within California and Oregon, and perhaps within the United States as a whole. Most residues for which soil incorporation is the best agronomical practice are already being plowed back, and those residues not being returned to the soil are usually not because it is not agronomically desirable. Therefore, for soil incorporation to make an impact, it must be shown to be as agronomically desirable as burning. This requires the development of new soil incorporation techniques or new breakthroughs in other areas of research, such as chemical control of pests and diseases. However, the introduction of chemicals for pest and disease control may produce undesirable environmental impacts. Finally, even if soil incorporation becomes as agronomically desirable as agricultural burning, it must still overcome the present cost disadvantage, and, to some extent, farmer reluctance to change disposal practices.

6.3.5 Alternative Residue Uses

Research efforts into alternative residue uses resulted primarily from the need to offset increased costs of alternatives to agricultural burning that required the collection and removal of the residues. Residue uses examined have been energy production, livestock feeds, pulp and paper products, and soil stabilizers.

In general, residue use in most markets faces economic handicaps. Most residues are dispersed, requiring costly collection; or far from markets, requiring costly transportation; limited in quantity, quality, or dependability, resulting in lower value to the buyer. In addition, the viability of alternative uses varies substantially among types of crop residues. For example, there are more potential uses for the residues from field crops such as wheat, barley, and corn than from rice.[53] Finally, farmer attitudes may play a very important part in the ultimate feasibility of any alternative use. In a report prepared by the Department of Agricultural Engineering, University of California, Davis, examining the use of agricultural residues for energy production, a survey of rice growers and fruit and nut growers found that "attempts to utilize the straw which require added expense or extra work for the grower will be resisted unless a stimulus exists that encourages ... them to accept the change."[53] The report also noted that the growers:

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[53] Horsfield, Brian C., Clarence Becker, and Bryan M. Jenkins. 1977. Agricultural Residues as an Alternative Source of Energy for the Pacific Gas and Electric Company. Department of Agricultural Engineering Research Report, University of California, Davis, California. 293 pp.

> ...tend to favor the idea of utilization of residues for energy. Growers also favor long-term contracts for the residue as long as the contracts do not seriously restrict their ability to run their farms as they desire. Especially important to growers is that a collection system not be declared an alternative disposal method for residues until actually proven as such through practical large-scale demonstrations. Technology developed specifically for collection residues will probably be slowly accepted by growers because of the large amounts of capital they have invested in farm machinery and reluctance to quit practices that have worked for them in the past.[53]

In California, there is a growing use of certain agricultural residues (almond and walnut) for the production of energy, which is proving to be very economical. Mr. James Morgester of the California Air Resources Board believes that prunings, rice, and field crop residues may be a viable energy source.

After 5 years of research efforts to solve the technical and economic problems that have hindered development of grass straw utilization, the State of Oregon concludes that "though some private straw utilization enterprises do exist, there is little expectation that any viable market will evolve with the short-term which will alleviate, to a significant degree, the negative effects of open field burning."[29]

6.3.6 Other Alternatives

Several other alternatives have been examined in addition to those discussed above. These include chemical control, plant growth regulators, and, for sugar cane, processing unburned cane.

In Oregon chemical control, on the whole, has been an ineffective substitute for agricultural burning in the control of various disease, pest, and weed infestations of grass seed crops. The Department of Environmental Quality in Oregon has designated research in this area to be a low priority because "of the high costs and length of time required for experimentation and development of new chemical control agents, as well as the potential environmental hazards associated with their use...."[29]

Researchers at the University of Idaho have studied the use of plant growth regulators, which modify certain aspects of plant physiology that affect growth and development, in order to improve grass yields. The objective of the study was "to screen a number of chemicals to determine their effects on yield and the time for most effective application."[54] The results from this study showed that plant growth regulators "do not appear to be a substitute for open-field burn or any other method of residue removal."[55]

Tests have been conducted in Hawaii[23] and Texas[56] on the feasibility of processing unburned versus burned sugar cane, and in Louisiana on the removal of trash by a wholestalk cane cleaner.[57] Results of the Hawaiian tests indicated that, when processing unburned cane, there is:

1. A substantial increase in harvesting and hauling requirements in terms of both men and equipment.
2. A moderate-to-substantial reduction in factory operating rates with existing facilities.

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[54] Ensign, R.D., Bruce Augustin, Mark Buettner, Peter Gray, Robert Hall, and Robert Nelson. 1974. Burning and Alternative Treatments for Kentucky Bluegrass Seed Production. Progress Report No. 188, Agricultural Experiment Station. University of Idaho, Moscow, Idaho. 31 pp.

[55] Ensign, R.D. and V.G. Hickey. Effects of Post-Harvest Residue Removal on Kentucky Bluegrass Growth and Development: Highlights of 8 years of Research. Progress Report No. 216, Agricultural Experiment Station, University of Idaho, Moscow, Idaho. 22 pp.

[56] Rozeff, Norman and H.R. Crawford, Jr. 1980. Green Cane vs. Burned Cane Harvest Comparisons, 1978-79. In Proceedings XVII Congress, International Society of Sugarcane Technologists. Volume I. Manila, Phillipines. 1980. pp. 916-931.

[57] Roberts, Darrell L. 1972. Status of the Development of a Whole Cane Cleaner. Louisiana Agricultural Experiment Station. 3 pp.

3. Nearly equal extraction at the reduced grinding rates but a slight reduction in boiling house recovery, with overall recovery being slightly less.
4. A small but significant improvement in yield of sugar/acre, apparently a result of smaller losses in the cleaning plant.
5. Substantially poorer sugar refinability in terms of both color and filterability.[23]

In a personal communication with the Hawaiian Sugar Planters' Association, harvesting unburned sugar cane would result in an estimated annual loss of $73 million to Hawaiian sugar cane growers, assuming a production of 1.1 million tons of sugar per year and a breakeven sugar price of $400 per ton.

Results from the Texas tests showed that harvesting green cane resulted in (1) a 7.41% sugar recovery loss and increased production costs 9.2% by reducing harvester, in field transport, trucking and milling efficiencies, and (2) 2.37 times more vegetative material left after harvesting than left in burned fields.[56]

Finally, results from the Louisiana tests during the 1970 and 1971 seasons showed somewhat favorable cleaning efficiency results and potentially favorable economics. The current status of the feasibility of a wholestalk cane cleaner has not been established.[57]

SECTION 7.0

FUTURE OF AGRICULTURAL BURNING

The following section provides an analysis of the future of agricultural burning in the United States over the next 20 years. A qualitative analysis for each region is given first followed by a quantitative analysis for the States of California and Oregon. In the first part, several factors that may affect the future of agricultural burning are discussed as well as the importance and potential effect of the factors for each region.

7.1 FACTORS AFFECTING THE FUTURE OF AGRICULTURAL BURNING

In general, the United States appears to be entering a period of relative stability in terms of agricultural burning as an environmental issue. Most states appear to have settled the issue and foresee no change in current policies in the near future. (Montana currently is revising its permit system.) Despite the high number of complaints in 1980, Oregon officials believe the State has settled its problems in the Willamette Valley to the satisfaction of all interested parties.[37] A number of factors could alter the present relative stability of burning and result in a change in either the extent of the practice, or the exposure to smoke of field fires, or perhaps to both. These factors include shifts in land use, farm practices, crops, technology, demographics, public concern, scientific knowledge, and public policy.

7.1.1 Land Use

The National Agricultural Lands Study (NALS) estimates that by the year 2000 demand for this country's agricultural products will increase between 55 and 80 percent over the 1980 level, assuming constant real prices; that in order to meet this demand, some 77 to 113 million acres of land for the production of principal crops would be needed; and that such a shift in land use to meet this demand is technically feasible.[58] This shift in land use affects the extent of agricultural burning in two ways. First, the net addition of agricultural land will increase the amount of agricultural residues burned to the extent crops whose residues are burned are grown on the additional lands. Second, as less agriculturally desirable land is brought into agricultural production, higher production costs will be incurred. As farmers seek to offset higher production costs, they may find burning of residues increasingly desirable as a cost-saving practice and thus increase its use. Also, farmers may find that to double crop (planting and harvesting two crops, usually different species, on the same land, one after the other, in 1 year) is more desirable if they currently "single" crop (plant and harvest one crop on land in 1 year) on the better agricultural land rather than bring poorer agricultural land into production. In order to turn the land over quickly enough to allow double cropping, farmers may need to burn residues.

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[58] U.S. Agricultural Department. 1981. National Agricultural Lands Study, Final Report 1981. U.S. Government Printing Office. Washington, D.C.

7.1.2 Farm Practices

Farm practices vary from region to region and from state to state due to parameters such as type of crop grown, soil characteristics, and prevailing climatic conditions. Allowing for this variability, the evolution of farm practices generally has resulted in a steady state of accepted farm practices within each region. However, as cited in earlier sections, some significant changes have occurred in the recent past due to technology innovations or education programs. In general, most farm practices appear to be established either as the best economical and agronomical farm practice or as the "traditional" farm practice; that is, the practice the farmer has always used and is hesitant to change. Thus, there does not appear to be much likelihood that changes in farm practices that reduce or increase agricultural burning will occur due to farm economics or agronomics; that is, without changes occurring in the other factors.

7.1.3 Crops

Market forces are a major factor affecting the types and amount of crops grown by the American farmer, and thus the types and amounts of agricultural residues that are normally burned. The NALS final report notes that "(g)iven the dynamic and complex nature of the U.S. agricultural system, it is impossible to predict exactly what combinations of resources will be most profitable for producers in the next two decades as the agricultural system expands output to meet a given level of demand."[58] In general, though, the NALS final report notes potential growth in corn production with the continuation of ethanol production and in staple food grains such as wheat and rice in response to worldwide demand increases.[58] Increases in wheat and rice production may result in direct increases in agricultural burning depending upon where they are grown (burn vs. nonburn areas) and whether the added production results in more double cropping.

7.1.4 Technology

The potential developments in technology are difficult to forecast. Past efforts to develop technologies to replace open field burning, such as the mobile field sanitizer and the whole cane harvester, have not proved successful. Efforts to develop an economical mobile field sanitizer have been discontinued in Oregon. In a few states, research to further reduce the need for agricultural burning and to reduce the exposure to its smoke will be continued. In Oregon, for example, research areas most likely to receive attention include (1) alternative residue use, (2) replacement crops, (3) refinement of meteorologically scheduled burns, and (4) refinement of fuel and fire management techniques. In California, most research is likely to focus on alternative residue uses, especially energy production. In Washington, it is the State's policy "to promote the development of economical and practical alternate agricultural practices to such burning [field and turf grasses grown for seed], and to provide for interim regulation of such burning until practical alternates are found."[59]

7.1.5 Demographics

During the 1970s there were two major population shifts - from urban to more rural areas and from the North to the South and the West.[58] These shifts have led to increased tensions between agricultural and nonagricultural land uses and between farmers and nonfarmers. The NALS study notes that while "the sociodemographic pressures in agricultural land will continue to increase over the next 20 years, they are not expected to increase as rapidly as they did during the late 1960s and early 1970s. Although future shifts in rural settlement are uncertain, the process of economic growth and development in rural areas is not expected to change significantly in the near future."[58]

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[59] Washington Air Act, 70.94.656. Open Burning of Field and Turf Grasses Grown for Seed - Alternatives - Studies - Funding - Procedures Limitations.

The changes in demographics are perhaps the most important factors affecting the future of agricultural burning, as public pressure over the adverse impacts (e.g., visibility reduction) appears to be the primary force behind any efforts for control, whether through regulation or research devoted to reducing emissions and exposures.

7.1.6 Public Concern

Public concern about agricultural burning is likely to continue and probably increase as farm and nonfarm populations become increasingly mixed. The NALS puts it thus:

> There is a basic incompatibility between many types of agricultural activity and residential use. As city people begin to move into rural areas, they object to the smells, noises, dust, pesticides, and other byproducts of operating a modern farm. These complaints can take several forms. Neighboring landowners may sue the farmer, claiming that certain routine farm activities are a nuisance. They may try to persuade the local government to pass an ordinance limiting various farm activities, or report the farmer to a county or state agency responsible for enforcing air or water pollution control laws and seek an order to end the offending farm practices.
>
> Farmers find that defending themselves against such actions can be expensive, time consuming, and aggravating, even when successful. They have turned with increasing frequency to their state legislators for protection. The laws that have been passed in response have been called "right-to-farm" laws. At least sixteen states have adopted some form of right-to-farm legislation.[58]

Table 13 in Section 6 shows the sixteen states as reported in the NALS report. Idaho since has passed in 1981 a right-to-farm bill increasing the difficulty of finding smoke from agricultural burning a "nuisance."[44] The extent to which increased public concern actually affects the extent of the practice depends upon a number of factors, such as the importance of agriculture to the state, the availability of economical and agronomical alternatives, and the relative political power of the proponents and opponents of burning.

7.1.7 Scientific Knowledge

Predicting what new scientific information will become available that will affect agricultural burning is difficult. Research is being continued to examine the potential health effects of the smoke. Should findings show a significant health impact or the presence of carcinogens or other mutagenic substances, then there will likely be a concerted effort to reduce open field burning. However, a determinative finding that its smoke does not adversely affect human health will have an impact of smaller magnitude on the issue as other aspects of smoke, especially visibility, will still be of major concern.

7.1.8 Public Policy

Most states appear to be set in their current public policies toward open burning whether they are considered restrictive or unrestrictive. Of the states contacted, only Montana foresaw any change in legislation or policy. Montana was in the process of revising its permitting system to require a permit only where 1,000 acres or more are to be burned. This change is expected to increase somewhat the amount of burning in the state. Some states indicated a strong agricultural presence in the state as a reason for the anticipated change.

7.2 REGIONAL ANALYSIS

The future of agricultural burning in the United States will vary depending on the magnitude and interaction of the factors discussed above.

Burning is likely to continue as an accepted farm practice in most parts of the country. Thus, as the expected agricultural expansion occurs, burning will increase proportionally with production of crops whose residues are normally burned. In addition, farmers may feel pressure to burn residues in order to offset higher production costs associated with bringing less desirable agricultural land into production burning (rather than to use a more costly disposal technique) to turn the land over quickly enough to facilitate double cropping.

On the other hand, demographic changes similar to the patterns of the last 10 years are expected to continue and reasonably may be expected to increase the tensions between farm and nonfarm populations over certain agricultural practices, including residue burning. This conflict is not likely to result in the abandonment of agricultural burning. Rather, the conflict will more likely result in attempts to implement fuel management and firing techniques, or even smoke management plans, to reduce emissions and exposures. The successful implementation of these controls will depend upon the additional costs imposed by these controls and the relative political power of the farm and nonfarm populations. Continued research into nonburning alternatives, especially soil incorporation and energy production, appears likely to be successful for certain crop residues or certain areas and, thus, allow for the reduction of agricultural burning.

7.2.1 Northeast

Agricultural analysts expect an increase in local farming due to higher food transportation costs caused by higher fuel costs.[58] The northeast has approximately 18.1 million acres of potential cropland to add to its base of 5.6 million acres. Increased orchard production, will determine primarily the extent to which use of the practice increases because orchard prunings appear to be the major source of agricultural burning in this region.[2] (Field crops are less important in the northeast than elsewhere, while poultry and dairy products make up over half the value of total farm output.)[58] Orchard prunings are difficult to pulverize, have long decomposition rates, and constraints on alternative methods are imposed by the presence of trees.[60] However, orchard prunings appear to have potential value as an alternative fuel source. If this value can be established then open field burning is likely to decrease significantly. Thus, there appears to be potential for a modest increase in the amount of burning and, at the same time, potential to reduce it, should an alternative energy technology be developed. As with other regions, the Northeast has experienced the shift of populations to the rural environs. However, given the limited extent of agricultural burning occurring now and the modest potential increase for the future, it is unlikely that there will be any major public pressure of policy changes towards the practice beyond what may exist now.

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[60] Freeman, Harry U. 1973. Problems and Opportunities in Management of Combustible Solid Wastes. International Research and Technology Corporation. Washington, D.C. EPA 670/2-73-056. 517 pp.

In summary, agricultural burning is not likely to be a major environmental issue in the Northeast requiring national attention. The worst case situation probably would only represent a modest increase in the amount of burning and a possible increase in conflict between grower and urbanite. Neither of these possibilities would be beyond local or, perhaps, state interest.

7.2.2 Midwest

The Midwest region currently contains approximately 55 percent of the nation's cropland.[58] The NALS report shows approximately 227.6 million acres in cropland and 40.6 million acres with high and medium potential for conversion to cropland.[61] Of the 40.6 million acres, 16 million acres are located in Nebraska (3.9 million), Kansas (5.5 million), and Missouri (6.6 million), the three states identified with the most agricultural burning in this region.

The number of agricultural areas in this region that will be brought into production is uncertain. The NALS has identified three major uncertainties: (1) "the decline of the underground water resources in some areas of the Northern Great Plains, especially in Kansas and Nebraska where irrigation has been so important to increasing productivity; (2) increased coal surface mining in the Corn Belt states, such as Illinois, and (3) corn-based ethanol production in the Midwest."[58] In addition, the NALS notes that many communities in this region are surrounded by prime agricultural land so that any growth in these communities will occur at the expense of agriculture.[58]

Much of the information about the future of agricultural burning in the Midwest region was obtained through personal communications with state environmental personnel and agricultural extension agents. In Kansas, Missouri, and Nebraska, there is little expectation of change in current burning practices in the near future. In Nebraska, burning is expected to continue to decrease as the older farmers move out of farming. In Kansas, population growth is not anticipated for areas near current agricultural burning centers. In Missouri, agricultural burning is regulated around the populated areas of Kansas City and St. Louis; and it is accepted practice in unregulated parts of the state.

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[61] National Agricultural Lands Study. 1981. Interim Report Number Five. America's Agricultural Land Base in 1977. 23 pp.

As noted above, the NALS report indicates many communities in the Midwest are surrounded by prime farmland. Growth in these communities might lead to increased tensions between farmer and nonfarmer. In Kansas, Nebraska, and Missouri agricultural burning as a practice is not likely to change due to population growth.

Elsewhere in the Midwest region, other disposal methods are used primarily. Therefore, increased agricultural production likely will not increase agricultural burning to any significant extent. The largest potential source of increased burning appears to be from any increase in orchard production and the burning of prunings, as the SRI report indicates orchard prunings as one of the primary residues "wasted" in this region.[2] However, this potential increase in absolute terms is likely to very small. Additional wheat acreage, in such states as North Dakota and South Dakota, are not likely to be burned. In North Dakota, all counties and townships are zoned for "no burn." In South Dakota, wheat straw is likely to be picked up for silage material or incorporated into the soil.

7.2.3 Southeast

The Southeast has the largest potential for increase in agricultural production than any other region, and, with the exception of Florida (extremely rapid population growth) and the Southern Great Plains (decline of groundwater supplies), propects for realizing this additional growth are generally good.[58] The NALS report indicates 60 million acres with a high or medium potential for conversion to cropland.[61] Constraints to this conversion are problems of soil erosion and competition for the land from forest production.[58]

The Southeast region practices agricultural burning on the whole to a much greater extent than any other region. In addition, state legislation in most states in the region tends to be very unrestrictive. Thus, there appears to be a large potential for an increase in its use as more land is brought into agricultural production.

Population shifts over the last decade or so are likely to continue, bringing more people into this region and into rural areas. This population shift, especially in conjunction with increased agricultural production, likely will increase tensions between farmer and nonfarmer populations. Should agricultural burning become a major issue, the resolution of the issue may result in the imposition of at least limited restrictions on agricultural burning in order to reduce emissions or exposures. Such restrictions likely would be in terms of fuel management and fire techniques and meteorologically scheduled burns. Administration of such regulations could be difficult and costly, since so many farms are owned by individuals, rather than by big business.

7.2.4 West

The West region is estimated to have 20 million acres of high or medium potential for conversion to cropland.[61] Of this, approximately 5.5 million acres are in California, Oregon, and Washington and approximately 5.7 million acres in Montana.

A number of constraints exist in the West.[58] Population growth creates perhaps the strongest pressures for conversion of existing cropland of anywhere else in the country. Limited water supplies for irrigation and high pumping costs, build-up of salts in the surface layer of the soil, and new urban growth and energy development projects make future production on both existing and potential agricultural land uncertain. In addition, of the 20 million potential acres for conversion to cropland, approximately 14 million acres are in rangeland, a use currently valued for grazing and the production of livestock. Of the 5.7 million acres in Montana, about 4.5 million acres would need to come from rangeland.

Agricultural burning in the West primarily occurs in California, Hawaii, Oregon, Washington, and in some parts of Idaho and Montana. At the same time, it is managed in California and Oregon by well-developed smoke management plans, and faces moderately high restrictions in Hawaii and Washington. Continued research is underway in such states as California, Oregon, and Washington to find methods to further reduce emissions and exposures.

In general, there seems to be a very limited potential for an actual increase in agricultural burning in this region. The largest potential appears to be in Montana, which has recently revised its regulations to require a permit only when 1,000 acres or more are to be burned. California, Oregon, and Washington are more likely than not to reduce the extent of its use in the future or, at least, in the case of Oregon, remain at the current level.

Idaho and the other states are likely to remain unchanged, with a limited potential for increase. In Hawaii, research into harvesting unburned sugar cane showed generally unfavorable economic impacts upon plantations.[23] In Hawaii, producers believe that any restriction on sugar cane burning is likely to create significant large economic burdens. Thus, there appears little prospect for reducing the amount of sugar cane burned without reducing the amount harvested. Finally, a personal communication with the Hawaiian Sugar Planters' Association indicated that the potential growth in the sugar cane industry is "negative" in Hawaii and "small, at best," for the domestic sugar cane industry. The reasons for this outlook were noted as primarily the absence of the Sugar Act, which had protected U.S. sugar producers until 1974, and the increasing acceptance of high fructose corn syrup as a substitute sweetner.

7.2.5 Other Regions

No information was obtained that would indicate any change in agricultural burning in Puerto Rico.

7.3 QUANTITATIVE ANALYSIS OF AGRICULTURAL BURNING

An attempt was made to conduct a quantitative trend analysis using the FUTURSCAN model. However, the complexity of the source and the scarcity of input data caused results of the analysis to be of limited usefulness. Insufficient historical data and difficulty in determining the technical relationship between events and their impacts (due to the large number of crop types, large number of outside factors affecting crop shifts, and the different effects the same event has on different crops) limit the usefulness of the results. Also, the results give little new information that is not already apparent from a careful study of the input data and event parameters. Furthermore, the probabilities of events vary among States, and the impacts of events vary among crops and states. Thus it is only feasible, at best, to use a futures model of agricultural burning for small geographic areas, such as the Willamette Valley in Oregon. These results are not applicable to other parts of the country for several reasons, including the absence of an event concerning increased agriculture production. That particular parameter was not considered for this study because increased production in the two study areas (California and Oregon) is questionable. Results using the FUTURSCAN model are included in Appendix A.

SECTION 8.0

APPENDICES

APPENDIX A - QUANTITATIVE ANALYSIS OF AGRICULTURAL BURNING TRENDS

APPENDIX B - TOTAL EMISSIONS OF CRITERIA POLLUTANTS RESULTING FROM AGRICULTURAL OPEN BURNING BY STATE AND NATIONWIDE

APPENDIX C - AGRICULTURAL BURNING EMISSION FACTORS

APPENDIX D - DERIVATION OF "ARTIFICIAL" HISTORICAL DATA FOR OREGON

APPENDIX E - HISTORICAL DATA FOR CALIFORNIA

APPENDIX F - DERIVATION OF EVENT PARAMETERS

APPENDIX G - TREND IMPACT ANALYSIS (TIA) TABLES

APPENDIX A

QUANTITATIVE ANALYSIS OF AGRICULTURAL BURNING

A quantitative analysis, using a program called FUTURSCAN, initially was planned for the entire United States. However, as the study progressed, it became evident that almost every state lacked the historical data necessary to perform the analysis. The best data available were for the Willamette Valley in Oregon and for California, though this data still did not meet the full requirements of the FUTURSCAN model. The following sections present the FUTURSCAN model briefly, the input data used in the model, and the results. These discussions are followed by a summary and discussion of the results.

A.1 The Model

FUTURSCAN is a trend impact analysis program, or trend forecasting procedure, which "combines mathematical trend extrapolation of historical data with human judgment about unprecedented future events to produce trend forecasts."[62]

Two types of information are required in using this program: historical data and unprecedented future events and their associated parameters. Using the historical data, the program first selects a "surprise free" mathematical extrapolation trend. The resulting trend, or curve, is selected on a "best fit" basis and may be one of 15 curves. Alternatively, the programmer may preselect the future extrapolation trend. Once the "surprise-free" trend is determined, the program then applies the selected unprecedented future events and their parameters to modify the surprise-free extrapolation. The program calculates the expected impact of the selected events, computing the expected value, or mean, and the upper and lower quantities of the distribution of possible impacts of each event.

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[62] The Futures Group. 1980. FUTURSCAN Program Manual: Trend Impact Analysis and Cost Impact Analysis. Glastonbury, Connecticut.

A.1.1 Historical Data. The first type of data required is historical data, which are used for the mathematical extrapolation of a "surprise-free" future. While the number of years of historical data required for extrapolation varies, a usual rule of thumb is to gather data for twice the number of years as the number of years for which a future is being forecast (e.g., if forecasting 20 years into the future, 40 years of historical data are required). Due to changes in the past, some of the historical data may not be relevant, and data generally should be collected for "that period of history that is expected to best indicate the future trend."[62]

The literature reviewed lacked historical data on the amount of agricultural burning done in any state except for Oregon (the Willamette Valley) and California. Personal communications were then made with state personnel and agricultural extensionists in approximately twelve other states, primarily in the midwestern and southern regions. For these other states, we found that (a) the amount of agricultural burning is not recorded, (b) or, where permits are required, the state does not keep aggregate records (thus requiring a hand search in a central office or at county offices), (c) the information on the permit is insufficient (e.g., lacks information of what is being burned), and (d) or if the information is aggregated, the state definition of "agricultural burning" includes sources not covered by this study, such as irrigation ditches, which may be a significant amount of the total agricultural burning. Only in California and Oregon were good historical data found, and even these data were available for only a limited period of time.

A.1.1.1 Willamette Valley, Oregon. Historical information was collected on the total number of acres burned in the Willamette Valley in Oregon for the years 1972 to 1981, the distribution of acres harvested among grass types for 1972 to 1981, and the particulate, hydrocarbon, and carbon monoxide emission factors for each grass type. Using this information, estimates were made of the annual emissions of each criteria pollutant. However, we felt that these historical data would not reflect that period of history which "best" indicates the future trend because of frequent changes in state legislation affecting agricultural burning: the state legislature (a) in 1971 passed a bill banning agricultural burning after January 1, 1975, contingent upon satisfactory development of an alternative to open field burning, (b) in 1975 replaced the ban with legislation requiring a phase-down in acreage burned from the 285,000 acres burned in 1974 to 50,000 acres in 1978 and thereafter, (c) in 1977, replaced the 1975 legislation with new legislation that in part, revised upward the number of acres that could be burned in 1977 and 1978 and gave authority to the Department of Environmental Quality (DEQ) to set acreage limitations beginning January 1, 1979, and thereafter, and (d) in 1979, significantly revised the 1977 legislation, in part, establishing 250,000 acres as the maximum allowable acreage to be burned each year and removing the authority previously given the DEQ to set annual acreage limitations. Further, a change in the law affecting the maximum allowable acreage appears unlikely in the near future. Due to the unstable legislative period, the data may not reflect a "typical" history that "best" indicates future trends in agricultural burning.

We determined that a set of "artificial" historical data, based on the assumption that 250,000 acres were burned from 1972 to 1981, rather than the actual number of acres burned, would better represent future emissions in the Willamette Valley. These "artificial" historical data are presented in Table A-1. (Appendix D shows the derivation of these emission estimates.)

TABLE A-1. EMISSION DATA, OREGON

	Emissions (tons per year)		
Year	Particulates	Hydrocarbons	Carbon Monoxide
1972	4,652	8,732	63,726
1973	4,628	8,724	63,698
1974	4,526	8,834	64,238
1975	4,442	9,078	65,625
1976	4,275	9,109	65,677
1977	4,069	9,334	66,805
1978	4,158	9,150	65,891
1979	4,295	9,000	65,182
1980	4,358	8,783	63,980
1981	4,470	8,852	64,658
AVG	4,388	8,960	64,948

Finally, we decided to have the FUTURSCAN program plot linear curves of the average emissions from 1972 to 1981 for each pollutant as their respective historical extrapolation trend baselines rather than allowing the program to select a "best fit" curve.

A.1.1.2 California. Total emission estimates for California for 1975 to 1980 were obtained from the California Air Resources Board (CARB). The estimates, except for 1976, included emissions from all sources defined by CARB as "agricultural burning." For both 1976 and 1980, individual emission estimates were obtained for each agricultural burning source. This breakdown of emission estimates and their sources revealed a difference in definition of agricultural burning sources used by CARB and in the present study. The total emission estimates for 1975, 1977, 1978, and 1979 therefore could not be used directly because they included emissions from sources, such as ditch burning, not included in the present study. As only total estimates (i.e., as opposed to the individual source estimates as for 1976 and 1980) were available for these 4 years, we could not determine directly the emission totals for only these agricultural burning sources covered by the present study. The emission data for these 4 years were therefore adjusted (see Appendix E) and are presented in Table A-2.

TABLE A-2. EMISSION DATA, CALIFORNIA
Emissions (tons per year)

Year	Particulates	Hydrocarbons	Carbon Monoxide
1975	27,333	21,305	146,097
1976	28,466	29,292	175,882
1977	19,121	14,326	113,900
1978	21,717	16,590	139,156
1979	20,781	14,649	158,223
1980	15,288	18,482	146,742

In contrast to Oregon, no significant recent event was noted that made us expect the future to be different from the last 6 years (1975-1980) in California. Therefore, the program was allowed to select the best fit future historical trend extrapolation baseline for each pollutant.

A.1.2 Selection of Events and Parameters. The second type of information needed is various, unprecedented future events that are likely to affect emissions from agricultural burning (see Table A-3).

Table A-3. SELECTED EVENTS FOR IMPACT ANALYSIS

Event Number	Event Name	Event Description
1	Sanitation Alternative	Development of an economical sanitation method, such as a mobile field sanitizer, that would replace the need for burning;
2	Alternative Residue Use	Development of alternative residue uses that make it more economical to collect and use rather than burn the residue;
3	Alternative Crop	Development of agronomically acceptable alternative crops that are more economically desirable and whose residues need not be burned;
4	Health Impacts	A finding that the smoke from agricultural burning produces significant adverse health impacts or contains carcinogens or other mutagenic substances;
5	Urbanization	Urbanization reduces the amount of acreage in agricultural production;
6	State Acreage Phasedown	State governments implement legislation reducing by 80 percent the number of acres that can be burned;
7	Federal Legislation	Federal legislation is implemented that reduces the amount of inhalable particulates that can be emitted; and
8	Decontrol Burning	Agricultural burning is decontrolled so that growers can burn as much residue as they want, whenever they want.

In addition to the selection of the events, various parameters for each had to be estimated. The parameters were the probability of occurrence of each event as a function of time (Table A-4), the maximum and steady-state impact of each event, and the number of years to first, maximum, and steady-state impact (Table A-5).

The selection of events and their parameters were based upon judgments derived from literature concerning agricultural burning in California and the Willamette Valley in Oregon and from personal communications with state personnel in Oregon and California. Two sets of impact estimates were developed, because the FUTURESCAN program cannot handle interdependency between individual event impacts, and there is a dependency between the impacts of each event. Set 1 reflects the independent impacts of each event, and Set 2 reflects estimates that attempt to account for the interdependency of the events' impacts with the model's program. (Appendix F contains more information on the derivation of the parameters used in the input data.)

A.2 Discussion of Input Limitations

Before presenting and discussing the results, several significant limitations are discussed. Problems exist with the length of historical data, the emission estimates of historical data and the compatibility of the impacts with the model design. The limitations are very important to the validity of the results, and therefore should be carefully considered.

A.2.1 Length of Historical Data The data bases for Oregon and California were very limited in terms of years of data available. As noted earlier, for projections 20 years into the future, historical data for 40 years would be ideal; 20 years would be acceptable. In California, historical data were available for only 6 years. Therefore, the extrapolation curve for 20 years is very suspect. In Oregon, due to the most recent change in State legislation, the historical data available were for a time period that did not reflect conditions likely to exist in the future. Therefore, the gross assumption was made to have FUTURSCAN model plot linear curves to represent the surprise free future historical extrapolation curve (as noted on page 73).

Table A-4. EVENT PROBABILITIES[a]

	Oregon			California		
EVENT	1987	1992	2002	1987	1992	2002
1. Sanitation Alternative	.02	.1	.13	.01	.08	.14
2. Alternative Residue Use	.16	.39	.43	.51	.76	.88
3. Alternative Crop	.18	.43	.53	.01	.04	.11
4. Health Impacts	.05	.12	.17	.09	.16	.28
5. Urbanization	.25	.49	.72	.01	.05	.14
6. State Acreage Phasedown	.12	.25	.49	.00	.00	.00
7. Federal Legislation	.21	.43	.64	.03	.11	.27
8. Decontrol Burning	.01	.03	.05	.01	.04	.11

[a] These probabilities represent calculated cross-impact probabilities.

TABLE A-5. EVENT IMPACT PARAMETERS[a]

Event	Years to First Impact	Years to Max. Impact	Years to Steady State Impact	Set 1						Set 2					
				Maximum Impact			Steady State Impact			Maximum Impact			Steady State Impact		
				Part.	HC	CO	Part.	HC	CO	Part.	HC	CO	Part.	HC	CO
1. Sanitation Alternative	7	12	15	-60	-60	-60	-45	-45	-45	-19	-18	-18	-16	-16	-16
2. Alternative Residue Use	5	8	11	-80	-80	-80	-60	-60	-60	-25	-24	-24	-22	-21	-21
3. Alternative Crop	2	5	8	-28	-52	-50	-18	-34	-32	-9	-16	-15	-7	-12	-11
4. Health Impacts	3	5	5	-50	-50	-50	-50	-50	-50	-16	-15	-15	-18	-17	-18
5. Urbanization	0	10	10	-20	-20	-20	-20	-20	-20	-6	-6	-6	-7	-7	-7
6. State Acreage Phasedown[b]	1	5	5	-80	-80	-80	-80	-80	-80	-25	-24	-24	-29	-28	-28
7. Federal Legislation	1	5	5	-10	-10	-10	-10	-10	-10	-3	-3	-3	-4	-3	-4
8. Decontrol Burning	0	3	3	+10	+13	+15	+10	+13	+15	+3	+4	+4	+4	+5	+5

[a] Same for both Oregon and California.

[b] This event was not used for California (see Appendix F).

A.2.2 Emission Estimates of Historical Data. As a linear curve was assumed to represent the future trend for emissions in Oregon, accuracy in emission estimates for the historical data would only affect the starting level of emissions and not the way the events affected the linear trend. On the other hand, errors in the values of the emission estimates for California could significantly change the historical extrapolation curve and the relative effects of the events on that curve. The adjusted emission estimates used in the program as California's historical data are suspect for 4 of the 6 years because of the gross assumption used to develop these estimates (as explained in Appendix E). At the same time, however, we believed that this gross assumption was necessary and the best available to us.

A.2.3 Treatment of Impact Estimates by the Model. FUTURSCAN assumes the impact of each event is independent of other events and, therefore, sums the individual impacts to arrive at a total impact. The impacts of the events for agricultural burning, however, are not independent but exclusionary. In other words, one acre of land "not burned" when one event occurs cannot again be "not burned" should another event also occur.

The independent impacts calculated for each event overestimate the total reduction in emissions from agricultural burning. Therefore, we developed a second set of impacts (see Appendix F) that we thought would represent the dependency of the events, and thus provide a better overall emission estimate, or at least provide a lower bound. The major drawback to the procedure used to calculate the second set of events is that it will underestimate the individual impact of any one event. Also, for combinations of events less than the maximum possible, the estimated reduction from the second set of impacts will be somewhat less than the "real" reductions. The two sets of impacts together may give some boundary as to the "real" reduction caused by the events, given the other limitations noted earlier.

A.3 Results

The results of the trend impact analyses are presented in Figures A-1 through A-6 for Oregon and Figures A-6 through A-12 for California. (Appendix G contains the tables which correspond to these figures and the methods used to generate the figures.) In each figure five curves

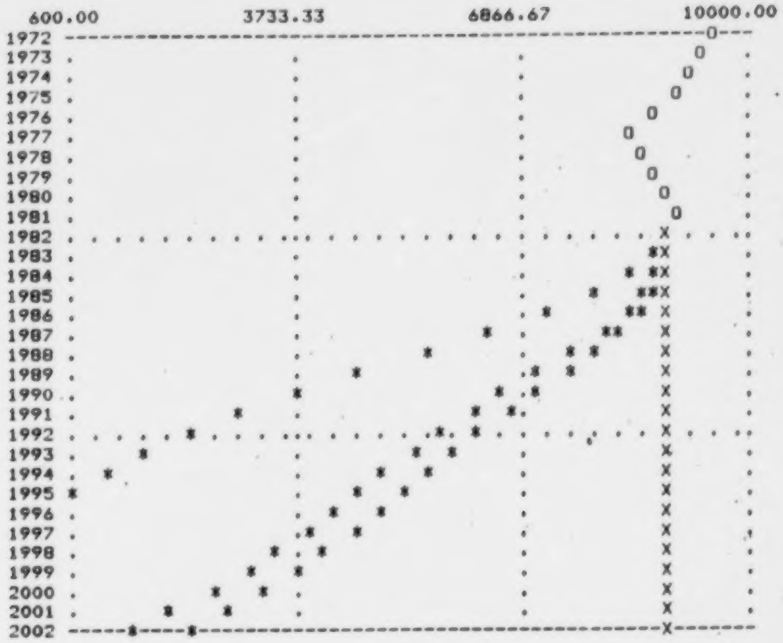

Figure A-1. Particulate TIA for Oregon, Set 1 Impacts

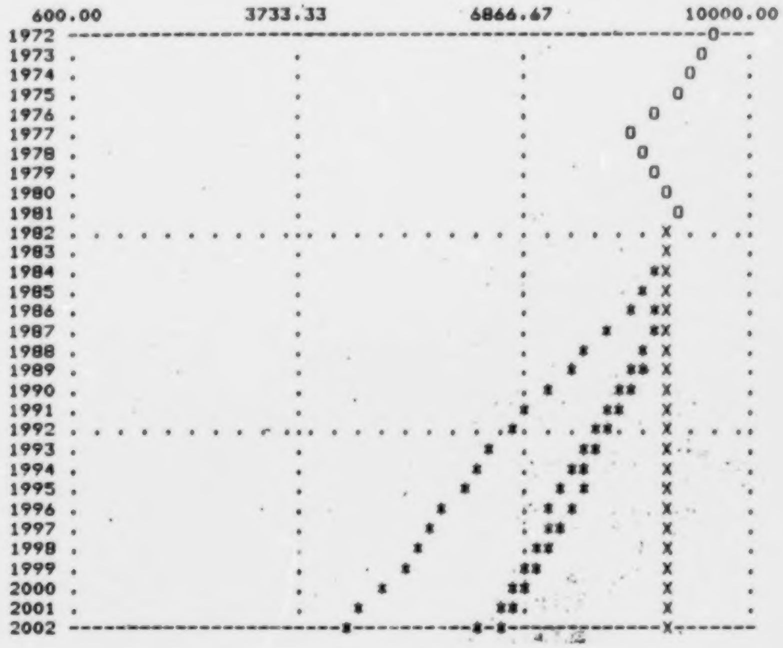

Figure A-2. Particulate TIA for Oregon, Set 2 Impacts

HISTORICAL DATA = 0
CALCULATED DATA = X
TIA FORECAST = *

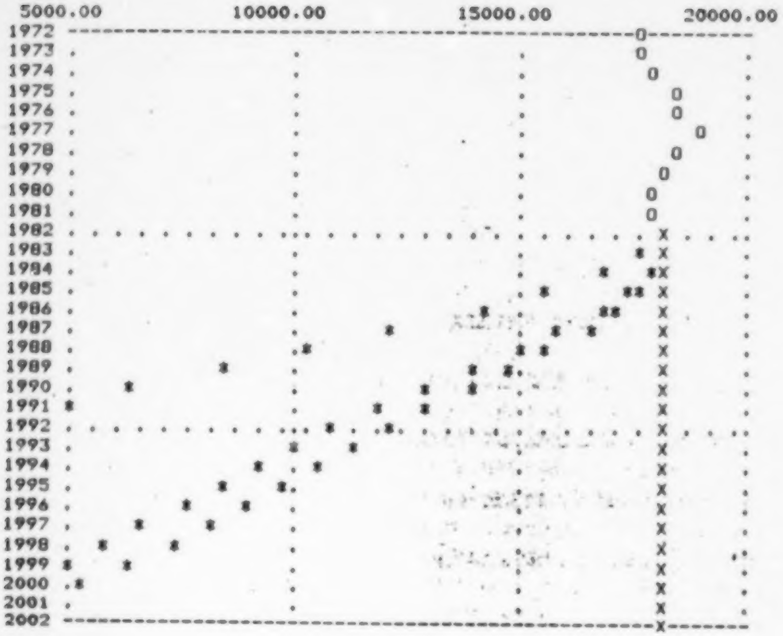

Figure A-3. Hydrocarbon TIA for Oregon, Set 1 Impacts

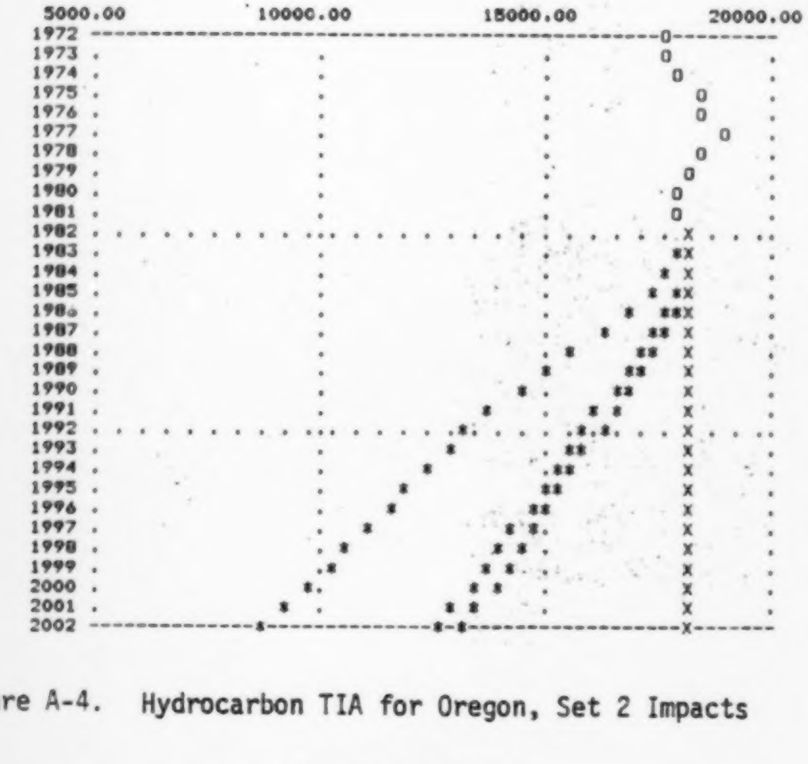

Figure A-4. Hydrocarbon TIA for Oregon, Set 2 Impacts

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CALCULATED DATA = X
TIA FORECAST = *

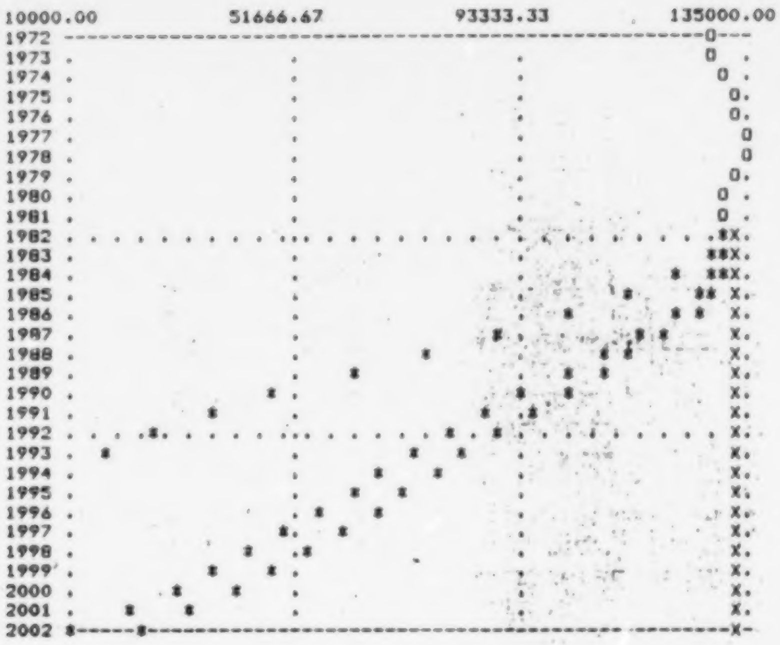

Figure A-5. Carbon Monoxide TIA for Oregon, Set 1 Impacts

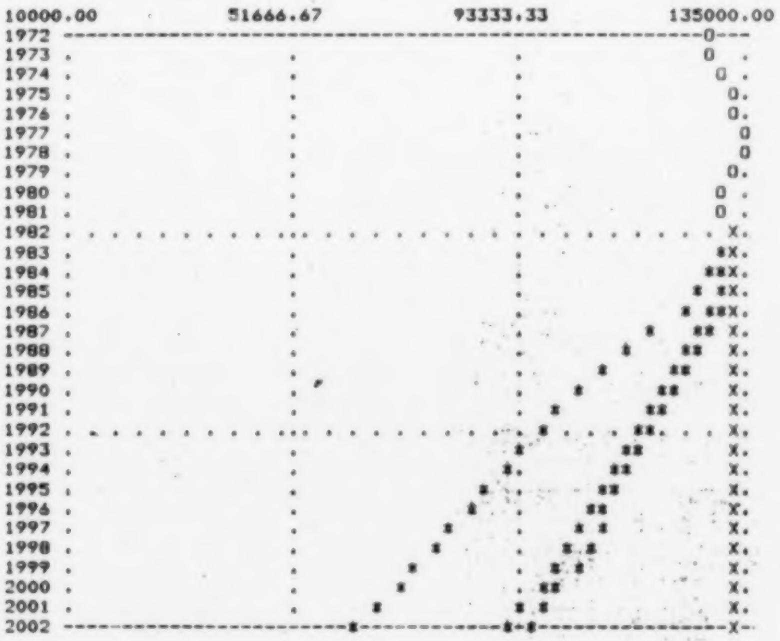

Figure A-6. Carbon Monoxide TIA for Oregon, Set 2 Impacts

HISTORICAL DATA = O
CALCULATED DATA = X
TIA FORECAST = *

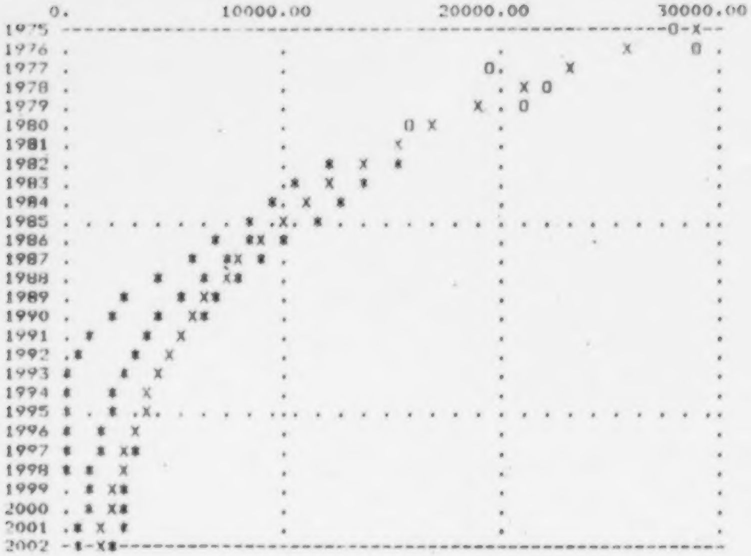

Figure A-7. Particulate TIA for California, Set 1 Impacts

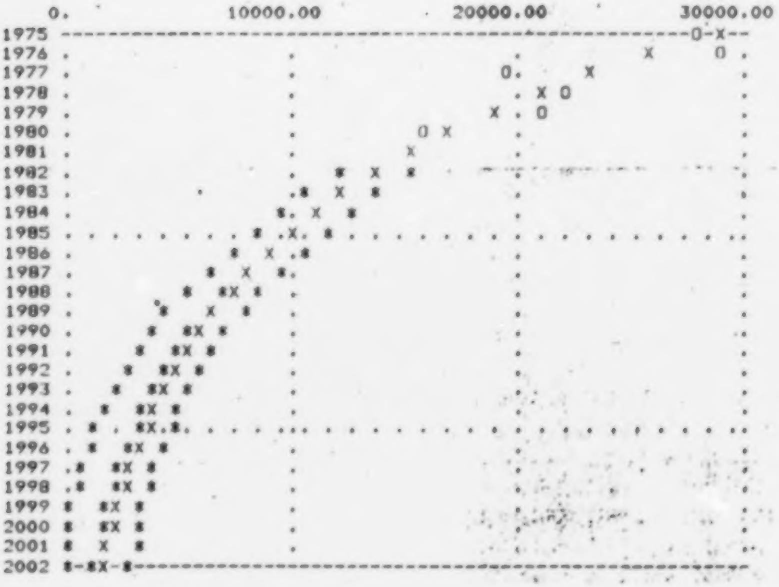

Figure A-8. Particulate TIA for California, Set 2 Impacts

HISTORICAL DATA = O
CALCULATED DATA = X
TIA FORECAST = *

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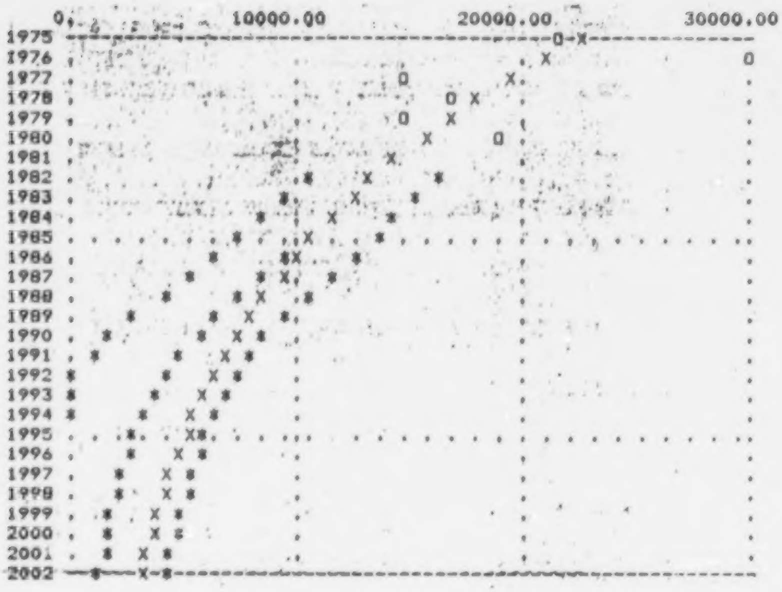

Figure A-9. Hydrocarbon TIA for California, Set 1 Impacts

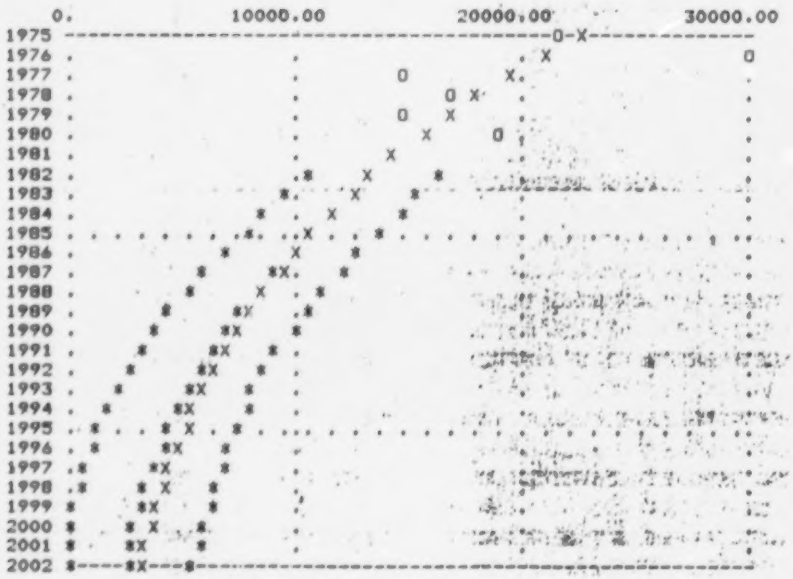

Figure A-10. Hydrocarbon TIA for California, Set 2 Impacts

HISTORICAL DATA = 0
CALCULATED DATA = X
TIA FORECAST = *

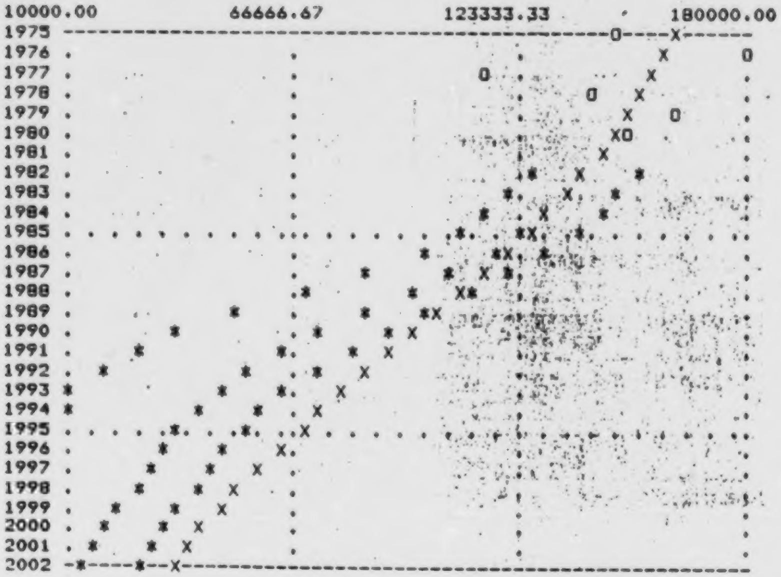

Figure A-11. Carbon Monoxide TIA for California, Set 1 Impacts

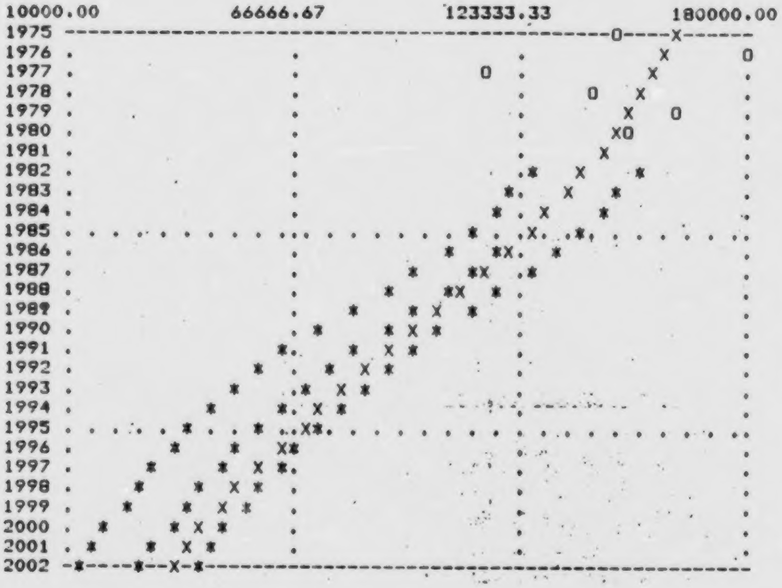

Figure A-12. Carbon Monoxide TIA for California, Set 2 Impacts

HISTORICAL DATA = O
CALCULATED DATA = X
TIA FORECAST = *

are shown: (1) historical data (0). (2) Surprise-free, future extrapolation (x). (3-5) Low, center, and upper future trends (*) estimated assuming the events in Table A-3 occur. The center future trend shows the mean forecast, and the upper and lower future trends represent upper and lower quartiles (i.e., 75 percent and 25 percent), containing 50 percent of the possible futures run using the input data specified in Tables A-4 and A-5.

Tables A-6 and A-7 show the effect of the events on the future trend, ranked from the event with the largest negative impact on the surprise free, historical trend, (at the top) to the event with the largest positive impact on the surprise free, historical trend (at the bottom). The ranking was obtained when the program was run and was the same within each state for both sets of impacts (i.e., Set 1 and Set 2 impacts in Table A-5).

TABLE A-6. RANKING OF EVENTS, OREGON

Rank	Particulate	Hydrocarbon and Carbon Monoxide
1	State Acerage Phasedown	State Acerage Phasedown
2	Alt. Residue Use	Alternative Residue Use
3	Urbanization	Alternative Crops
4	Alternative Crops	Urbanization
5	Health Impacts	Health Impacts
6	Federal Legislation	Federal Legislation
7	Sanitation Alternative	Sanitation Alternative
8	Decontrol Burning	Decontrol Burning

TABLE A-7. RANKING OF EVENTS, CALIFORNIA

Rank	Particulate	Hydrocarbon and Carbon Monoxide
1	Alternative Residue Use	Alternative Residue Use
2	Health Impact	Health Impacts
3	Federal Legislation	Alternative Crops
4	Sanitation Alternative	Federal Legislation
5	Alternative Crops	Sanitation Alternative
6	Urbanization	Urbanization
7	Decontrol Burning	Decontrol Burning

A.4 Discussion of Results

A.4.1 Oregon. In Oregon, each trend impact analysis (Figures A-1 through A-6) shows a relatively sharp reduction in emissions from the surprise-free historical trend extrapolation. This reduction is much more pronounced for the first set of impacts than for the second. Both of these results were expected given the predominance of negative impacts and the relative size of impacts between Set 1 and Set 2 impacts.

The events found to cause the largest decrease in emissions were the state acreage phasedown and alternative residue use. Alternative crops and urbanization events caused the third or fourth largest decrease in emissions, depending upon the criteria pollutant of concern. The difference in ranking of these latter two events is due primarily to the lower particulate relative to the hydrocarbon and carbon monoxide emission reduction potential of the alternative crop event. Even though the maximum particulate emission reduction potential for the alternative crop event is larger than that of the urbanization event, the combination of event probabilities and the latter's higher steady state particulate emission reduction potential result in the urbanization event having a larger particulate emission reduction than the alternative crop event.

A.4.2 California. In California, the surprise free historical extrapolation curve, representing the best fit selected by the program, shows a dramatic decrease in emissions occurring in the future. The trend impact analysis forecasts show the center forecast to be equivalent or slightly below the historical extrapolation curve. The upper and lower curves vary from the center curve relatively little. The three trend impact analysis curves indicate that the future events have a relatively small effect on the future of agricultural burning, as shown by the historical extrapolation curve. However, given the questionable nature of the historical data base, no conclusion as to the actual affect of the events on the future of agricultural burning can be drawn.

Of the future events, alternative residue use and health impacts have the largest negative impact on the future trend. The difference in the ranking between Particulate, and Hydrocarbons and Carbon Monoxide for the event, Alternative Crops, is due to the difference in impacts on the criteria pollutants caused by this event.

A.4.3 Comparison of Oregon and California. Assuming the surprise-free historical extrapolation curves are accurate estimates of the future trends, the events have a much greater impact in Oregon than in California. However, as noted earlier, given the questionability of the historical extrapolation curve for California, this may not be true to the extent indicated by the results.

Excluding state acreage phasedown, which was not included in the trend impact analysis for California, the alternative residue use event caused the largest emission reduction in both areas. After this, significant differences in the ranking occurred. For example, health impacts caused the second largest reduction in emissions in California but only the fifth (or fourth excluding state acreage phasedown) largest reduction in the Willamette Valley. The reason for this and the other differences in ranking are due to the differences in the event probabilities for the two areas.

A.5 Conclusions

For Oregon, the trend analysis shows little more than can be inferred from careful consideration of events and their parameters: agricultural burning is likely to decrease and to a large degree when certain events occur.

For California, due to the questions concerning the historical data and its extrapolation curve, no conclusion can be made as to what impacts the events might have (e.g., whether the impacts would be the same where relatively small effects are shown or would be like Oregon, where relatively large effects are shown). The two states that were modeled do represent unique cases particularly because for these states it was only possible to identify events with downward impacts on agricultural burning. States such as those in the southeastern United States, where exceptional agricultural growth is likely to occur, may present much more elaborate and interesting trend analyses. Unfortunately, historic data necessary to conduct such trend analyses are sparse or non-existent for these areas.

APPENDIX B - TOTAL EMISSIONS OF CRITERIA POLLUTANTS RESULTING FROM AGRICUTURAL OPEN BURNING BY STATE AND NATIONWIDE[a,3]

Location	Particulates, metric tons/yr	Hydrocarbons, metric tons/yr	CO, metric tons/yr	NO_x, metric tons/yr
Alabama	1,400	1,600	8,100	160
Arizona	170	200	1,000	20
Arkansas	980	1,200	5,800	120
California	26,000	31,000	153,000	3,100
Colorado	1,200	1,400	7,200	140
Delaware	17	20	100	2
Florida	15,000	17,000	86,000	1,700
Georgia	7,500	8,800	44,000	880
Hawaii	10,000	12,000	59,000	1,200
Idaho	190	220	1,100	22
Kansas	4,600	5,400	27,000	540
Kentucky	490	2,900	580	58
Louisiana	16,000	19,000	95,000	1,900
Maine	280	330	1,000	33
Maryland	60	70	350	7
Massachusetts	26	30	150	3
Michigan	790	930	4,700	93
Minnesota	2,300	2,700	14,000	270
Mississippi	5,200	6,200	31,000	620
Missouri	1,500	1,800	9,100	180
Montana	1,300	1,500	7,600	150
Nebraska	2,600	3,000	15,000	300
Nevada	43	50	250	5
New Mexico	17	20	100	2
North Carolina	5,300	6,200	31,000	620
North Dakota	3,700	4,400	22,000	440
Ohio	1,200	1,400	7,100	140
Oklahoma	1,400	1,600	8,100	160
Oregon	4,100	4,800	24,000	480
Pennsylvania	590	690	3,500	69
South Carolina	320	380	1,900	38
South Dakota	2,300	2,700	13,000	270
Tennessee	520	610	3,100	61
Virginia	370	430	2,200	43
Washington	2,200	2,600	13,000	200
Wisconsin	1,200	1,500	7,300	150
Wyoming	290	340	1,700	34
National Total	113,000	132,000	662,000	13,200

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[a] Calculated by multiplying the emission factors by the total burning done in the state. Emission factors assumed representative of agricultural open burning were selected.

APPENDIX C

AGRICULTURAL BURNING EMISSION FACTORS

The primary source of emission factors for agricultural burning and other air pollution sources is AP-42. However, since the factors reported in the AP-42 are a generalized summary from several research studies, they do not convey as much information as may be desired. For example, several of the research studies report a breakdown of the types of hydrocarbons emitted for several crops (Tables C-1 and C-2). The type of hydrocarbon emitted may be important for estimating potential health or environmental impacts. For example, ethylene, the major constituent of olefins, has a direct, injurious effect on a few types of ornamental flowers at ambient concentrations.[63] In addition, other pollutants, such as nitrogen oxides, which are principal in initiation of photochemical reactions and aldehydes, which are highly reactive, are present in the smoke and merit consideration. (Further research may determine their importance as agricultural burning pollutants.) In another study[64] emission factors for specific types of grasses grown in the Willamette Valley (Tables C-3 and C-4) are reported. This variation in emission factors may be important when only one type of grass burning is of concern.

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[63] 63. Darley, Ellis, F. 1979. Hydrocarbon Characterization of Agricultural Waste Burning. Final Report, California Air Resources Board Project A7-068-30, Statewide Air Pollution Research Center, University of California, Riverside, California. 53 pp.

[64] 64. Boubel, Richard W., Ellis F. Darley, and Edward A. Schuck. 1969. Emissions from Burning Grass Stubble and Straw. Journal of the Air Pollution Control Association, (17)9:497-500.

Table C-1. ETHENE, OLEFINS, AND SATURATES PLUS ACETYLENES MAXIMUM EMISSION FACTORS (lbs/ton) FOR RICE STRAW BARLEY STRAW, AND FRUIT PRUNINGS[65]

	Ethene	Olefins	Saturates Plus Acetylenes
Rice	1.7	2.5	0.7
Barley	2.2	3.5	1.1
Fruit Prunings - 1965	0.8	1.3	0.5
1966	2.7	4.1	1.3

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[65] Darley, E.F., F.R. Burleson, E.H. Mateer, J.T. Middleton, and V.P. Osterli. 1966. Contribution of Burning of Agricultural Wastes to Photochemical Air Pollution. Journal of the Air Pollution Control Association (11)12:685-690.

Table C-2. HYDROCARBON, NO_x, AND ALDEHYDE EMISSION FACTORS FOR EIGHT CROPS[49]

	EMISSION FACTORS (lbs/ton)							
Hydrocarbons[a]	Barley	Corn	Rice	Sorghum	Wheat	Almond	Grape	Peach
Benzene[b] UCR(ARLI)	(0-778)	(0.093)	(0.099)	(0.028)	(0.734)	(0.116)	(0.084)	(0.104)
	(0.247)	0.129	0.057	0.125	0.424	0.099	0.127	0.116
Toluene	(0.297)	(0.061)	(0.027)	(0.001)	(0.185)	(0.022)	(0.033)	(0.028)
	0.130	0.037	0.024	0.020	0.120	0.022	0.037	0.036
Ethylbenzene	0.019	0.005	0.006	0.003	0.020	0.002	0.006	0.045
p-Xylene	0.006	0.003	0.002	0.002	0.008	0.001	0.003	0.003
m-Xylene	0.020	0.005	0.006	0.005	0.019	0.003	0.007	0.007
o-Xylene	0.010	0.008	0.004	0.003	0.011	0.001	0.003	0.003
Tetrachloroethane	--	0.012	--	--	--	0.012	0.010	--
Chlorobenzene[b]	--	0.004	0.013	0.006	--	0.001	0.003	0.003
Styrene	0.021	0.007	0.005	--	0.041	0.002	0.005	0.004
Furfural	0.028	0.005	--	--	0.014	0.004	--	0.008
1,2,4 Tetramethylbenzene	0.004	--	0.003	--	0.005	0.003	--	--
p/m Ethylbenzene	--	--	--	--	0.004	--	--	--
Phenylacetylene	--	--	--	--	0.004	--	--	--
Benzaldehyde[b]	0.008	--	--	--	--	--	--	--
Benzofuran	0.010	--	0.001	--	0.008	0.001	--	--
Indene	0.007	--	0.003	--	0.007	--	0.002	--
Napthalene[b]	0.009	--	0.003	0.003	0.013	0.003	0.002	0.006
NO_x[c]								
NO_x headfire (backfire)	1.9 (2.9)	2.4(2.7)	3.2(3.2)	2.7(3.0)	1.7(2.1)	1.7	2.5	2.5
NO_2 headfire (backfire)	1.5 (1.0)	0.3(0.3)	0.9(1.1)	0.5(0.4)	1.2(0.8)	0.6	1.3	0.9
Aldehydes[c,d]								
Isobutyrladehyde[e]	11.3	--	--	5.0(3.4)	6.3(8.2)	4.3	4.6	--
Crotonalydehyde[e]	4.8(0.1)	0.7	0.8(2.8)	2.7(0.2)	8.3(0.2)	0.9	0.8	--
Hexanaldehyde[e]	--	0.8	1.8(12.1)	3.9(1.8)	--(0.01)	0.1	--	0.6

---

[a] Emission factors for hydrocarbons above C_6. Samples were analyzed by University of Calfornia, Riverside (UCR) and Analytical Research Laboratories, Inc. (ARLI). Only headfire results are reported for the 5 field crops. Pile fine results are reported for the three orchard crops.

[b] Low reactivity.

[c] Pile fire results are reported for the three orchard crops.

[d] Results are of limited value since yield was very erratic and only three materials were found with any degree of consistency.

[e] High degree of reactivity according to the California Air Resources Board Reactivity Classification of Organic Compounds.

Table C-3. YIELDS OF VARIOUS POLLUTANTS FROM GRASSES COLLECTED IN THE WILLAMETTE VALLEY, OREGON, AND BURNED IN THE TOWER AT THE UNIVERSITY OF CALIFORNIA, RIVERSIDE,[50]

	Pounds/Ton of Grass Burned									
Grass	% Moisture	Particulate	CO_2	CO	C	Sat.[a] + Acet.	Olefins	Ethylene	C Bal. %	NO_x at Temp Peak ppm
					Dry Series					
Blue	5	16.5	2786	147	18	3.3	3.1	2.4	107	72
Per. Rye	6	12.0	2483	104	14	2.1	3.2	1.4	100	49
Bent	2	14.0	2557	124	14	2.1	2.0	0.9	98	21
Ann. Rye	9	10.5	2666	85	8	0.9	1.2	0.6	103	23
Fescue	9	13.0	2737	122	12	2.5	2.4	1.2	107	45
Orchard	15	11.5	2469	89	7	1.2	1.2	0.7	100	27
					Dry-Green Series					
Blue	23	15.0	2407	95	8	1.0	2.0	1.2	111	44
Per. Rye	71	26.0	678	106	19	2.4	5.6	3.4	77	4
Bent	60	24.0	1277	109	19	2.1	5.0	3.1	94	13
Ann. Rye										
1	20	9.0	1855	56	4	0.4	1.0	0.6	103	37
2	55	11.0	969	60	6	0.8	2.4	1.8	102	--
Fescue	66	17.0	925	77	9	1.2	2.6	1.8	94	8
Orchard										
1	66	18.0	645	86	14	1.4	3.3	2.1	87	12
2	47	17.0	1558	113	16	1.7	4.0	2.3	90	5

[a] Without methane.

Table C-4. RESULTS OF SUMMER 1967 FIELD BURNS OF VARIOUS GRASSES.[65]

Burn No.	Grass	Lb Particulate/ Ton Fuel	Lb CO/ Ton Fuel	Lb HC/ Ton Fuel	Ambient Temp., °F	R.H. %	Wind Speed, mph
2	Blue	81.23	238	14.75	89.8	32	9
3	Orchard	15.54	130	10.78	71.5	50	6
4	Orchard	8.47	140	11.18	90.2	24	6
5	Perennial Rye	10.23	133	10.68	70.5	61	3
6	Red Fescue	1.31	102	9.14	79.8	64	11
7	Red Fescue	12.65	120	9.90	88.0	34	0
9	Perennial Rye	8.78	118	9.41	80.0	51	2
10	Perennial Rye	8.75	107	9.41	80.0	62	1
11	Red Fescue	5.24	126	10.02	84.0	64	12
12	Annual Rye	3.33	108	10.27	100.0	24	9

APPENDIX D

DERIVATION OF "ARTIFICIAL" HISTORICAL DATA FOR OREGON

The following table shows the amount of grass harvested in Oregon from 1972 through 1981 estimates. These quantities were obtained in a personal communication with state personnel.[66]

Table D-1. GRASS ACRES HARVESTED IN OREGON, 1972-1981[66]

	Acres Harvested (x 1000)									
Grass Type	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Bluegrass	28	27	26	20.5	19	17	18	18	18	18
Bentgrass[a]	9.2	9.5	9.2	8.3	5.6	5.4	7.3	7.5	8.7	9.9
Fescues	49	47	44.5	38	32.5	31.5	34	33.5	37	39
Orchardgrass	22	22	18	12.5	13	11	14	16	17	18
Perennial Ryegrass	43	50	53	48	44	44	60	60	68	74
Annual Ryegrass	130	130	137	132	122	136	142	127	120	115
TOTAL	281.2	285.5	287.7	259.3	236.1	244.9	275.3	262	268.7	273.9

[a] These amounts represent about 1/3 of the total bentgrass acreage harvested in the state, as about 1/3 is grown in the Willamette Valley and 2/3 in the rest of the state. (Personal communication).

The quantities harvested were adjusted proportionately among each grass type to reflect the assumption that 250,000 acres were burned each year. Table D-2 illustrates this adjustment for 1973.

Table D-2. ADJUSTMENT OF 1973 ACREAGE DATA

Grass Type	1973 Acres Harvested	x	Factor	=	1973 "Artificial" Acreage Burned
Bluegrass	27		250/285.5		23.6
Bentgrass	9.5		"		8.3
Fescues	47		"		41.2
Orchardgrass	22		"		19.3
Perennial Ryegrass	50		"		113.8
Annual Ryegrass	130		"		43.8
TOTAL	285.5				250.0

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[66] O'Connell, S. Department of Environmental Quality, California. November 16, 1981. Personal communication.

The "artificial" acreage burned estimates were calculated for each year. Total emissions for each year and each pollutant were made using the estimated "artificial" acreages burned and the following factors:

Table D-3. FACTORS USED IN ESTIMATING EMISSIONS

Grass Type	Residue Factor[39] (tons/acre)	Emission Factors[64,a] (lbs/ton) Particulate	HC	CO
Bluegrass	1.5	81.2	23.0	238
Bentgrass	1.5	81.2	23.0	238
Fescues	2.6	6.4	15.1	116
Orchardgrass	4.15	12.0	17.1	135
Annual Ryegrass	6.0[b]	3.3	16.0	108
Perennial Ryegrass	3.65	9.2	15.2	119

[a] Emission factors for bentgrass are assumed same as for bentgrass.
[b] Based on various reported estimates, 6 tons per acre was selected as representative.

For example, total particulates for 1973 were estimated to be 4,628 tons as follows:

Table D-4. TOTAL PARTICULATE EMISSION ESTIMATE FOR 1973

Grass Type	Acres Burned (x1000)	x Residue Factor	x Emission Factor (lb/acre)	= Emissions (tons)
Bluegrass	23.6	1.5	81.2	1,437
Bentgrass	8.3	1.5	81.2	506
Fescues	41.2	2.6	6.4	343
Orchardgrass	19.3	4.15	12.0	480
Annual Ryegrass	113.8	6.0	3.3	1,127
Perennial Ryegrass	43.8	3.65	9.2	735
TOTAL				4,628

APPENDIX E

HISTORICAL DATA FOR CALIFORNIA

The following estimates from agricultural burning were obtained from the California Air Resources Board.[67]

Table E-1. CRITERIA POLLUTANT EMISSION ESTIMATES FOR CALIFORNIA, 1975-1980[67]

	Emissions (tons)		
Year	Particulate	Hydrocarbon	Carbon Monoxide
1975	39,888	39,787	301,686
1976	28,466	29,292	175,882
1977	31,676	32,808	269,489
1978	34,272	35,072	294,745
1979	33,336	33,131	313,812
1980	27,843	29,457	302,332

Except for 1976, the estimates included sources not considered as "agricultural burning" within this study.

Information was available for 1980 that allowed the calculation of emissions from agricultural burning as defined in this study. These emissions were calculated to be 15,288 tons of particulates; 18,482 tons of hydrocarbons, and 146,742 tons of particulates. Emissions from "non" agricultural burning sources were thus 12,555 tons for particulate; 10,975 for hydrocarbons; and 155,590 for carbon monoxide.

As no other information was readily available to "breakdown" the estimates for 1975, 1977, 1978, and 1979, the gross assumption that "non" agricultural burning emissions in 1975, 1977, 1978, and 1979 were the same as in 1980 was made. This assumption yielded the following estimates, which were used in the quantitative analysis.

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[67] Smith, J. Air Resources Board, California. November 17, 1981. Personal communication.

Table E-2. "ADJUSTED" EMISSION ESTIMATES FOR FOR CALIFORNIA, 1975-1980

	Adjusted Emissions (tons)		
Year	Particulate	Hydrocarbon	Carbon Monoxide
1975	27,333	28,812	146,096
1976	28,466	29,292	175,882
1977	19,121	21,833	113,900
1978	21,717	24,097	139,156
1979	20,781	22,156	158,223
1980	15,288	18,482	146,742

APPENDIX F

DERIVATION OF EVENT PARAMETERS

Initial estimates were made for each event parameter based upon the literature review, which did not indicate any major reasons to suspect that the event parameters would vary significantly between Oregon and California. Except for the event probabilities, the initial estimates, which were the same for both Oregon and California, were used. Personal communications with state personnel in Oregon and California indicated that there are likely differences between the two states in terms of the probabilities of the events. In addition, probability estimates different from the initial estimates were given in these conversations. We decided to use these "new" probability estimates (Table F-1) rather than our initial estimates, in the cross-impact analysis program to determine the probabilities used in the trend impact analysis. Once the initial probabilities were determined, a cross-impact analysis was run. This analysis required an estimation of the effect on the probabilities of each event occurring given that one of the events had already occurred. These estimates were determined based on what seemed to be reasonable relationships in terms of the direction of the effect (i.e., increase, decrease, or no effect on the initial probability), although the magnitude of the effect is subject to one's own judgment. (See Tables F-2 through F-7.) In some instances, it was felt that the occurrence of one event did not affect the probability of occurrence for another event. In some instances, two events were seen as mutually exclusive: if one occurred, the probability of the other occurring was zero.

Years to first, maximum, and steady-state impacts were estimated, where possible, using qualitative statements from the literature review. There is a possibility that the events in California might move more slowly than in Oregon due to the greater complexity of agriculture in California than in Oregon, where the events affect only one valley. However, the size of the variation was not known. Therefore, the same

Table F-1. PROBABILITIES FOR OREGON AND CALIFORNIA*

	Year		
Event	1987	1992	2002
Oregon			
1. Sanitation Alternative	.01	.05	.15
2. Alternative Residue Use	.10	.30	.50
3. Alternative Crop	.15	.40	.60
4. Health Impacts	.05	.15	.30
5. Urbanization	.25	.50	.75
6. State Acreage Phasedown	.10	.20	.50
7. Federal Legislation	.20	.40	.60
8. Decontrol Burning	.01	.05	.15
California			
1. Sanitation Alternative	.01	.05	.15
2. Alternative Residue Use	.50	.75	.90
3. Alternative Crop	.01	.05	.15
4. Health Impacts	.1	.2	.4
5. Urbanization	.01	.05	.15
6. State Acreage Phasedown	0.00	.00	.00
7. Federal Legislation	.01	.05	.15
8. Decontrol Burning	.01	.05	.15

*NOTE: These represent cumulative probabilities. Thus, if the probability between 1992 and 2002 were the same (e.g., .15 and .15) this would mean 0% chance of the event occurring between 1992 and 2002.

Table F-2. CROSS IMPACT PROBABILITIES FOR 1987, OREGON

If this event occurs ... / It will affect the probability of this event ...	INITIAL Probability	1. Sanitation Alternative	2. Alternative Residue Use	3. Alternative Crop	4. Health Impacts	5. Urbanization	6. State Acreage Phasedown	7. Federal Legislation	8. Decontrol Burning
1. Sanitation Alternative	.01		.005	.00	.10	.25	.20	.15	.15
2. Alternative Residue Use	.01	.01		.03	.10	.25	.20	.15	.02
3. Alternative Crop	.10	.00	.02		.30	.25	.20	.25	.02
4. Health Impacts	.10	.01	.02	.03		.25	.20	.07	.02
5. Urbanization	.25	.005	.02	.30	.30		.20	.25	.15
6. State Acreage Phasedown	.20	.00	.05	.10	.30	.25		.25	.02
7. Federal Legislation	.15	.01	.005	.03	.03	.25	.20		.02
8. Decontrol Burning	.05	.00	.02	.50	.25	.15	.50	.35	

Table F-3. CROSS IMPACT PROBABILITIES FOR 1992, OREGON

If this event occurs ... / It will affect the probability of this event ...	INITIAL Probability	1. Sanitation Alternative	2. Alternative Residue Use	3. Alternative Crop	4. Health Impacts	5. Urbanization	6. State Acreage Phasedown	7. Federal Legislation	8. Decontrol Burning
1. Sanitation Alternative	.05		.02	.00	.30	.50	.40	.40	.30
2. Alternative Residue Use	.05	.05		.10	.30	.50	.40	.40	.07
3. Alternative Crop	.20	.00	.10		.50	.50	.40	.50	.07
4. Health Impacts	.30	.05	.10	.10		.50	.40	.20	.07
5. Urbanization	.50	.02	.10	.50	.50		.40	.50	.30
6. State Acreage Phasedown	.40	.00	.15	.20	.50	.50		.50	.07
7. Federal Legislation	.40	.05	.02	.10	.15	.50	.40		.07
8. Decontrol Burning	.15	.00	.10	.70	.50	.30	.75	.60	

Table F-4. CROSS IMPACT PROBABILITIES FOR 2002, OREGON

If this event occurs ... / It will affect the probability of this event ...	INITIAL Probability	1. Sanitation Alternative	2. Alternative Residue Use	3. Alternative Crop	4. Health Impacts	5. Urbanization	6. State Acreage Phasedown	7. Federal Legislation	8. Decontrol Burning
1. Sanitation Alternative	.15		.07	.00	.50	.75	.60	.60	.30
2. Alternative Residue Use	.15	.15		.25	.50	.75	.60	.60	.15
3. Alternative Crop	.50	.00	.15		.50	.75	.60	.60	.15
4. Health Impacts	.50	.15	.15	.25		.75	.60	.35	.15
5. Urbanization	.75	.07	.15	.80	.50		.60	.60	.30
6. State Acreage Phasedown	.60	.00	.15	.50	.50	.75		.60	.15
7. Federal Legislation	.60	.15	.07	.25	.25	.75	.60		.15
8. Decontrol Burning	.30	.00	.15	.85	.50	.50	.90	.60	

Table F-5. CROSS IMPACT PROBABILITIES FOR 1987, CALIFORNIA

If this event occurs ... / It will affect the probability of this event ...	INITIAL Probability	1. Sanitation Alternative	2. Alternative Residue Use	3. Alternative Crop	4. Health Impacts	5. Urbanization	6. State Acreage Phasedown	7. Federal Legislation	8. Decontrol Burning
1. Sanitation Alternative	.01		.005		.50	.01	.01	.01	.20
2. Alternative Residue Use	.01	.01			.50	.01	.01	.01	.05
3. Alternative Crop	.00								
4. Health Impacts	.50	.01	.02			.01	.01	.005	.05
5. Urbanization	.01	.005	.02		.75		.01	.03	.20
6. State Acreage Phasedown	.01	.00	.05		.75	.01		.03	.05
7. Federal Legislation	.01	.01	.005		.20	.01	.01		.05
8. Decontrol Burning	.10	.00	.02		.70	.005	.50	.05	

Table F-6. CROSS IMPACT PROBABILITIES FOR 1992, CALIFORNIA

If this event occurs ... / It will affect the probability of this event ...	INITIAL Probability	1. Sanitation Alternative	2. Alternative Residue Use	3. Alternative Crop	4. Health Impacts	5. Urbanization	6. State Acreage Phasedown	7. Federal Legislation	8. Decontrol Burning
1. Sanitation Alternative	.05		.02		.75	.05	.05	.05	.40
2. Alternative Residue Use	.05	.05			.75	.05	.05	.05	.10
3. Alternative Crop	.00								
4. Health Impacts	.75	.05	.10			.05	.05	.02	.10
5. Urbanization	.05	.02	.10		.85		.05	.07	.40
6. State Acreage Phasedown	.05	.00	.15		.85	.05		.07	.10
7. Federal Legislation	.05	.05	.02		.35	.05	.05		.10
8. Decontrol Burning	.20	.00	.10		.90	.02	.75	.15	

Table F-7. CROSS IMPACT PROBABILITIES FOR 2002, CALIFORNIA

If this event occurs ... / It will affect the probability of this event ...	INITIAL Probability	1. Sanitation Alternative	2. Alternative Residue Use	3. Alternative Crop	4. Health Impacts	5. Urbanization	6. State Acreage Phasedown	7. Federal Legislation	8. Decontrol Burning
1. Sanitation Alternative	.15		.07		.90	.15	.15	.15	.40
2. Alternative Residue Use	.15	.15			.90	.15	.15	.15	.20
3. Alternative Crop	.00								
4. Health Impacts	.90	.15	.15			.15	.15	.07	.20
5. Urbanization	.15	.07	.15		.90		.15	.15	.40
6. State Acreage Phasedown	.15	.00	.15		.90	.15		.15	.20
7. Federal Legislation	.15	.15	.07		.50	.15	.15		.20
8. Decontrol Burning	.40	.00	.15		.90	.07	.90	.15	

years to first, maximum, and steady-state impacts were used. The following part briefly discusses some of the rationale used in selecting these parameters for each event.

1. Sanitation Alternative --

   Years to First Impact: 7

   Growers are slow to accept change in their practice for essentially unknown/unfamiliar practices. It has been said of the mobile field sanitizer that once developed an "additional 5 to 10 years of use assurance to the farmer might be required to entice its purchase." A midpoint of 7 years was selected.

   Years to Maximum Impact: 12

   After acceptance by growers, another 5 years seems reasonable to allow all those who might use it to try it.

   Years to Steady-State Impact: 15

   It is assumed that it takes 3 years after using the alternative sanitation method that a grower will determine whether or not to continue using it or go back to burning.

2. Alternative Residue Use --

   Years to First Impact: 5

   Once an economic alternative has been found, the growers will need to be shown, for example, that the residue can be collected without harm to their crops, much the same as with the sanitation alternative.

   Years to Maximum Impact: 8

   Assumes that once an alternative use has been adopted, adoption by all those who are willing to try the alternative use will occur fairly quickly, over a 3-year period.

   Years to Steady-State Impact: 11

   Assumes that it takes 3 years for all those who will stay with the alternative use to make up their minds.

3. Alternative Crop --

   Years to First Impact: 2

   Assumes that there will be an initial trial of new crops by a limited number of farmers fairly soon after the economics of the crop have been shown.

Years to Maximum Impact: 5

Assumes that growers who attempt to change crops will be at maximum rate 3 years after first impact.

Years to Steady-State Impact: 8

Assumes that adjustments are made within 3 years of maximum impact in that some farmers drop out and others startup.

4. Health Impacts --

Years to First Impact: 3

By the time things are set in motion to the occurrence of this event, up to 3 years could likely pass by the time the first impact is felt.

Years to Maximum Impact: 5

Once things are set in motion, impact should reach maximum fairly quickly.

Years to Steady-State Impact: 5

Assumed to be the same as years to maximum impact.

5. Urbanization --

Years to First Impact: 0

Once urbanization takes place, the land is sold and no burning occurs.

Years to Maximum Impact: 10

Assumes that it will take 10 years to acquire all the land necessary for urbanization.

Years to Steady-State Impact: 10

See discussion under "Steady-State Impact" for this event on page 115.

6. State Phasedown --

Years to First Impact: 1

Assumes that upon passage, 1 year will elapse before taking effect.

Years to Maximum Impact: 5

Assumes that the phasedown will occur over a 4-year period as was in Oregon's mid-1960s acreage reduction law.

Years to Steady-State Impact: 5

Assumed to be the same as years to maximum impact due to the nature of the legislation.

7. Federal Legislation --

Years to First Impact: 1

Assume a 1-year lag period before passage of such legislation affects agricultural burning.

Years to Maximum Impact: 5

Assumes that 4 years pass for full compliance to occur.

Years to Steady-State Impact: 5

Assumed to be same as years to maximum impact due to nature of legislation.

8. Decontrol Burning --

Years to First Impact: 0

Decontrolling burning is likely to result in changing farming practice quickly, especially as it usually is more economical to burn than to dispose of residue in other ways. Farmers on the whole prefer burning.

Years to Maximum Impact: 3

This will not occur instantly. Farmers will require time to adjust to decontrol situation. Increase plantings in crops that were not being grown due to control of burning may occur. Time to maximum impact, though, is likely to be farily rapid.

Years to Steady-State Impact: 3

Assumed to be same as years to maximum impact. For reasoning, see discussion on "Steady-State Impact" for this event on page 116.

The maximum and steady-state impacts of each event were estimated first for Oregon. Calculation of these impacts were made as follows: Baseline acres burned over a 12-year period, 1970 to 1981, were established (using the method in Appendix D), from which average acres burned for each grass types were determined (see Table F-8). Next, estimates were made on the change in acreage burned, by grass type, each event might cause. Once the new acreages burned were determined, emissions for each criteria pollutant were re-calculated. These emission estimates were compared with the average emission estimates calculated in Appendix D. The percent difference in the two emission

Table F-8. MAXIMUM (Steady-State) ACRES BURNED (x 10^3) FOR EACH ALTERNATIVE BY GRASS TYPE Willamette Valley, Oregon

	GRASS TYPE					
Event	Bentgrass	Bluegrass	Fescue	Orchardgrass	Annual Ryegrass	Perennial Ryegrass
Baseline	20.3	7.5	36.8	15.2	121.9	48.1
1. Sanitation Alternative	6.8 (10.2)	2.5 (3.8)	30.67 (32.2)	5.1 (7.6)	40.6 (66.0)	16.0 (24.2)
2. Alternative Residue Use	4.1 (8.1)	1.5 (3.0)	7.4 (14.7)	3.0 (6.1)	24.4 (48.8)	9.6 (19.2)
3. Alternative Crop	18.3 (19.3)	6.8 (7.1)	33.1 (35.0)	13.7 (14.4)	30.5 (61.0)	43.3 (45.7)
4. Health Impacts	10.2	3.8	18.4	7.6	60.9	24.1
5. Urbanization	18.8	6.8	27.9	14.2	118.0	44.2
6. State Acreage Phasedown	4.1	1.5	7.4	3.0	24.4	9.6
7. Federal Legislation	18.3	6.8	33.1	13.7	109.7	43.3
8. Decontrol Burning	22.8	8.4	41.2	17.0	136.6	53.9

estimates, which represent emissions before and after the event, was then calculated and used as the estimated impact. For three events, we felt that the steady-state impacts would differ from the maximum impacts. We therefore adjusted the acreage burned to reflect our assumptions as to what the steady-state impacts might be. This set of impacts reflect the independent impacts of each event, that is, the impact of each event assuming all other events do not occur.

Due to the large number of crops in California, the approach used to estimate the maximum and steady-state impacts of each event in Oregon was unmanageable for application to California. In addition, with the large number of variables in California, assumptions concerning the effects of each event on changes in crop acreage were more difficult to apply reasonably. Therefore, the gross assumption that the maximum and steady state impacts of the events were the same for California as for Oregon were made.

Finally, a second set of maximum and steady-state impacts were calculated. This set of impacts was calculated from the first set, which represents the independent impacts of each event, in an attempt to account for the interdependency of the event impacts. The method selected was not "ideal" in terms of representing the actual interdependency between impacts, but may better represent the actual situation than the first set of impacts. The second set of impacts was calculated by dividing the independent impact of each event for each criteria pollutant by the respective sum of the independent impacts for each criteria pollutant. Thus, the maximum reduction possible is 100 percent (allowing for rounding error) should all events occur. (We realize and note that the exclusionary aspects of certain events (e.g., decontrol burning and state acreage phasedown) prevent all events from occurring at the same time.) Also, the second set of impacts would sum to over 100 percent when all events except decontrol burning occurred. This method is illustrated in Table F-9.

The following part briefly discusses the assumptions made concerning changes in acreage burned in the Willamette Valley, Oregon, effected by each event. The changes in acreage burned were used to calculate the maximum and steady-state impacts.

Table F-9. CALCULATION OF SECOND SET OF IMPACTS

Event	First Set of Impacts (%) Maximum, Particulate			Second Set of Impacts (%) Maximum, Particulate
1. Sanitation Alternative	-60	$\frac{60}{318}$	=	-19
2. Alternative Residue Use	-80	$\frac{80}{318}$	=	-25
3. Alternative Crop	-28	$\frac{28}{318}$	=	-9
4. Health Impacts	-50	$\frac{50}{318}$	=	-16
5. Urbanization	-20	$\frac{20}{318}$	=	-6
6. State Acreage Phasedown	-80	$\frac{80}{318}$	=	-25
7. Federal Legislation	-10	$\frac{10}{318}$	=	-3
8. Decontrol Burning	+10	$\frac{10}{318}$	=	+3
SUM	-318			-100

1. Sanitation Alternative --

   Maximum Impact.

   The sanitation alternative was assumed to be tried on a maximum of 2/3 of all grass acreage (i.e., only 1/3 of the grass acreage would be burned), except for fescue grass acreage. Fescue does not respond well to nonburning techniques. Therefore, the sanitation method was assumed to be tried on a maximum of 1/6 of all fescue acreage.

   Steady-State Impact.

   In the end, 1/2 of all grass acreage was assumed to use the alternative sanitation method, except for fescue where 1/8 of the acreage would use the alternative sanitation method.

2. Alternative Residue Use --

   Maximum Impact.

   Assumes that at maximum 80 percent of all grass growers in Oregon would try the alternative use method. Eighty percent was proportioned among grass types for lack of better distribution information.

   Steady-State Impact.

   Assumes that 60 percent of all grass growers decide to stay with alternative use. Sixty percent was again proportioned among grass types as no information was available to provide a better assumption.

3. Alternative Crop --

   Maximum Impact.

   Assumes that 75 percent of all annual ryegrass acreage is switched to meadowfoam and that 10 percent of all other grass acreage will be switched to either meadowfoam or rapeseed. High rate for annual ryegrass is due to the relatively poor economic return on annual ryegrass relative to the other grasses.

   Stead-State Impact.

   Assumes that 50 percent of annual ryegrass acreage and 5 percent of all other grass acreage will continue to grow the alternative crop.

4. Health Impacts --

Maximum Impact.

Assumes 50 percent reduction in number of acres burned is the result of this event occurring. The reduction in number of acres burned was proportioned among each grass type.

Steady-State Impact.

Assumed to be same as maximum impact.

5. Urbanization --

Maximum Impact.

Assumes that all grass acreage in Washington, Clackamas, and Yamhill Counties and one-third of the grass acreage in Lane County are lost to urbanization, as these counties are located next to the major urban areas of the Willamette Valley. All lost grass acreage was assumed to have been burned.

Steady-State Impact.

Assumes no acreage cost to urbanization is regained either through reclamation of acreage from urbanization and no increase in acreage elsewhere in the valley to compensate for lost acreage. This latter assumption is not too bad as types of grass lost are either unable to be grown on soils in areas not affected by urbanization or are low profit margin crops to begin with.

6. State Phasedown --

Maximum Impact.

Assumes an 80 percent reduction in acres being burned and proportioned among acres by grass type.

Steady-State Impact.

Same as for maximum impact due to nature of the legislation.

7. Federal Legislation --

Maximum Impact.

The impact of federal legislation is virtually impossible to determine because of so many variables. For the purpose of this study, it was assumed that total inhalable particulate emissions must be reduced by 20 percent and that this reduction was distributed in the same proportion among each source as the proportion each source contributes to the total amount of inhalable particulate emissions. For example, if one source is responsible for 25 percent of the total inhalable particulate emissions, then 25 percent of the necessary 20 percent reduction must come from this source. A preliminary study[24] shows that agricultural burning contributes approximately 50 percent of the Willamette Valley's inhalable particulate emissions. Therefore, half of the 20 percent reduction is to come from reduced agricultural burning emissions (i.e., particulate emissions from agricultural burning are assumed to be reduced by 10 percent).

Steady-State Impact.

Assumed to be the same as the maximum impact by nature of the legislation.

8. Decontrol Burning --

Maximum Impact.

Personal communications with Oregon's Department of Environmental Quality indicated that between 270,000 and 280,000 acres of grass would be burned if burning was decontrolled. In calculating new emissions, it was assumed that 280,000 acres would be burned and that the proportion of grass type being burned would be the same as for the average emissions. This last assumption (proportionally) was based on the relative difficulty of shifting between types of grass grown in the Willamette Valley and the lack of any other information to provide a better assumption.

Steady-State Impact.

The steady-state impact does not seem likely to differ significantly from the maximum impact. Any change in direction would be downward. Some argument could be made for public pressure being put on growers to reduce burning even though it has been decontrolled, with the growers responding by some reduction. This is in essence what occurred in Oregon during the 1960s. At the same time, better understanding of burning under favorable meteorological conditions to lessen the exposure but not the amount of emissions may effectively counter this potential public pressure. Thus, it was assumed reasonable to keep steady-state impact at same level as maximum impact with as a consequence no change in years to steady-state impact.

APPENDIX G

TREND IMPACT ANALYSIS (TIA) TABLES

TABLE G-1. TIA FOR PARTICULATES, OREGON, SET 1 IMPACTS

		FORECAST		
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1972	9303.82			
1973	9255.40			
1974	9051.54			
1975	8882.78			
1976	8549.00			
1977	8138.38			
1978	8316.38			
1979	8590.10			
1980	8717.06			
1981	8940.86			
1982	8774.53	8738.68	8768.25	8778.73
1983	8774.53	8523.31	8721.46	8757.18
1984	8774.53	8172.74	8615.75	8689.67
1985	8774.53	7678.49	8438.92	8561.69
1986	8774.53	7047.21	8190.61	8369.45
1987	8774.53	6219.17	7824.02	8069.98
1988	8774.53	5408.15	7415.65	7722.53
1989	8774.53	4565.05	6974.69	7344.31
1990	8774.53	3670.69	6504.21	6941.17
1991	8774.53	2892.46	6059.77	6548.30
1992	8774.53	2205.49	5641.30	6169.56
1993	8774.53	1613.91	5261.90	5818.79
1994	8774.53	1039.07	4887.36	5470.30
1995	8774.53	486.28	4517.98	5123.78
1996	8774.53	-45.21	4153.76	4778.77
1997	8774.53	-574.72	3787.57	4431.94
1998	8774.53	-1108.85	3414.90	4078.78
1999	8774.53	-1710.48	2980.27	3667.00
2000	8774.53	-2383.73	2488.90	3206.00
2001	8774.53	-3131.21	1942.53	2701.13
2002	8774.53	-3962.55	1340.75	2154.43

TABLE G-2. TIA FOR PARTICULATES, OREGON, SET 2 IMPACTS

		FORECAST		
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1972	9303.82			
1973	9255.40			
1974	9051.54			
1975	8882.78			
1976	8549.00			
1977	8138.38			
1978	8316.38			
1979	8590.10			
1980	8717.06			
1981	8940.86			
1982	8774.53	8763.77	8772.65	8775.79
1983	8774.53	8696.66	8758.26	8769.22
1984	8774.53	8587.28	8725.45	8748.30
1985	8774.53	8432.73	8670.46	8709.61
1986	8774.53	8234.95	8593.04	8650.15
1987	8774.53	7930.99	8467.00	8549.52
1988	8774.53	7644.63	8326.97	8431.32
1989	8774.53	7353.55	8175.78	8301.67
1990	8774.53	7049.73	8014.40	8162.66
1991	8774.53	6775.90	7858.71	8025.21
1992	8774.53	6520.55	7704.99	7886.93
1993	8774.53	6298.82	7564.74	7758.05
1994	8774.53	6083.74	7426.12	7629.84
1995	8774.53	5876.17	7289.07	7502.09
1996	8774.53	5675.66	7153.58	7374.73
1997	8774.53	5476.97	7017.61	7246.67
1998	8774.53	5280.20	6881.49	7118.10
1999	8774.53	5063.87	6726.42	6971.30
2000	8774.53	4826.39	6553.72	6808.86
2001	8774.53	4566.83	6363.85	6632.43
2002	8774.53	4282.30	6156.52	6442.27

TABLE G-3. TIA FOR HYDROCARBONS, OREGON, SET 1 IMPACTS

			FORECAST	
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1972	17464.73			
1973	17445.71			
1974	17666.76			
1975	18155.45			
1976	18218.22			
1977	18667.46			
1978	18301.34			
1979	18001.05			
1980	17565.67			
1981	17703.58			
1982	17919.00	17846.00	17906.40	17932.17
1983	17919.00	17406.64	17811.30	17891.00
1984	17919.00	16606.69	17563.84	17733.25
1985	17919.00	15436.24	17139.11	17429.21
1986	17919.00	13924.78	16536.16	16966.46
1987	17919.00	11962.03	15659.40	16255.80
1988	17919.00	10133.15	14711.71	15444.79
1989	17919.00	8298.63	13711.83	14575.96
1990	17919.00	6407.80	12671.42	13669.90
1991	17919.00	4746.87	11689.62	12792.90
1992	17919.00	3273.99	10766.24	11950.46
1993	17919.00	2001.34	9928.00	11169.88
1994	17919.00	756.01	9097.31	10393.29
1995	17919.00	-450.74	8274.76	9619.78
1996	17919.00	-1619.61	7460.36	8848.27
1997	17919.00	-2783.92	6641.96	8072.80
1998	17919.00	-3956.77	5810.56	7284.54
1999	17919.00	-5265.79	4852.91	6376.36
2000	17919.00	-6712.40	3785.03	5372.08
2001	17919.00	-8300.30	2610.50	4281.91
2002	17919.00	-10047.61	1328.16	3108.75

TABLE G-4. TIA FOR HYDROCARBONS, OREGON, SET 2 IMPACTS

			FORECAST	
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1972	17464.73			
1973	17445.71			
1974	17666.76			
1975	18155.45			
1976	18218.22			
1977	18667.46			
1978	18301.34			
1979	18001.05			
1980	17565.67			
1981	17703.58			
1982	17919.00	17897.11	17915.23	17923.11
1983	17919.00	17765.32	17886.71	17910.87
1984	17919.00	17523.70	17811.96	17863.30
1985	17919.00	17169.79	17683.79	17774.21
1986	17919.00	16712.49	17501.62	17635.47
1987	17919.00	16044.75	17219.45	17410.57
1988	17919.00	15434.77	16913.49	17151.08
1989	17919.00	14830.12	16589.37	16870.59
1990	17919.00	14213.18	16250.67	16575.57
1991	17919.00	13654.74	15924.93	16285.90
1992	17919.00	13133.72	15604.56	15996.04
1993	17919.00	12678.61	15310.54	15724.50
1994	17919.00	12235.02	15019.20	15454.11
1995	17919.00	11804.32	14730.22	15184.28
1996	17919.00	11385.90	14443.60	14914.83
1997	17919.00	10970.98	14155.95	14643.85
1998	17919.00	10560.26	13868.23	14372.05
1999	17919.00	10111.50	13543.30	14064.37
2000	17919.00	9623.72	13185.40	13727.31
2001	17919.00	9095.12	12795.26	13363.88
2002	17919.00	8520.50	12372.17	12973.98

TABLE G-5. TIA FOR CARBON MONOXIDE, OREGON, SET 1 IMPACTS

YEAR	HISTORY/ BASELINE	FORECAST		
		LOWER	CENTER	UPPER
1972	127451.22			
1973	127397.13			
1974	128474.64			
1975	131248.57			
1976	131353.82			
1977	133609.00			
1978	131782.39			
1979	130363.31			
1980	127960.50			
1981	129315.12			
1982	129895.57	129367.46	129805.28	130014.37
1983	129895.57	126184.72	129118.12	129732.75
1984	129895.57	120447.93	127346.96	128617.62
1985	129895.57	112078.09	124311.41	126456.68
1986	129895.57	101276.04	120003.33	123149.63
1987	129895.57	87234.44	113729.97	118057.92
1988	129895.57	74116.74	106942.58	112251.57
1989	129895.57	60930.01	99777.13	106032.16
1990	129895.57	47310.84	92314.79	99544.11
1991	129895.57	35360.89	85274.34	93265.10
1992	129895.57	24771.80	78654.13	87234.41
1993	129895.57	15630.11	72647.84	81650.56
1994	129895.57	6687.53	66696.26	76094.67
1995	129895.57	-1973.84	60803.72	70560.36
1996	129895.57	-10359.15	54970.23	65039.95
1997	129895.57	-18712.35	49107.74	59490.65
1998	129895.57	-27126.99	43152.39	53850.40
1999	129895.57	-36529.16	36283.08	47343.25
2000	129895.57	-46933.58	28612.75	40139.67
2001	129895.57	-58368.47	20167.37	32314.21
2002	129895.57	-70967.97	10937.20	23883.44

TABLE G-6. TIA FOR CARBON MONOXIDE, OREGON, SET 2 IMPACTS

YEAR	HISTORY/ BASELINE	FORECAST		
		LOWER	CENTER	UPPER
1972	127451.22			
1973	127397.13			
1974	128474.64			
1975	131248.57			
1976	131353.82			
1977	133609.00			
1978	131782.39			
1979	130363.31			
1980	127960.50			
1981	129315.12			
1982	129895.57	129736.87	129868.21	129925.36
1983	129895.57	128781.51	129661.52	129836.61
1984	129895.57	127059.66	129129.36	129498.08
1985	129895.57	124549.78	128219.78	128865.37
1986	129895.57	121310.25	126928.44	127880.00
1987	129895.57	116450.91	124865.66	126229.00
1988	129895.57	112011.20	122630.43	124328.77
1989	129895.57	107607.22	120263.55	122277.51
1990	129895.57	103109.24	117789.36	120120.38
1991	129895.57	99035.92	115407.47	118000.30
1992	129895.57	95232.25	113062.90	115877.44
1993	129895.57	91927.91	110926.31	113903.38
1994	129895.57	88707.68	108809.17	111937.43
1995	129895.57	85581.64	106709.17	109975.36
1996	129895.57	82545.16	104626.30	108015.81
1997	129895.57	79534.00	102535.88	106045.28
1998	129895.57	76553.23	100445.00	104068.73
1999	129895.57	73296.59	98084.36	101832.32
2000	129895.57	69754.94	95483.09	99381.63
2001	129895.57	65914.77	92646.54	96738.67
2002	129895.57	61737.80	89569.49	93902.97

TABLE G-7. TIA FOR PARTICULATES, CALIFORNIA, SET 1 IMPACTS

			FORECAST	
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1975	27333.00			
1976	28466.00			
1977	19121.00			
1978	21717.00			
1979	20781.00			
1980	15288.00			
1982	13409.24	11847.91	13409.01	14970.11
1983	12056.52	10494.24	12055.41	13616.54
1984	10840.26	9268.06	10830.58	12391.80
1985	9746.70	8156.46	9722.87	11284.17
1986	8763.46	7099.22	8679.31	10241.16
1987	7879.41	6110.40	7711.48	9274.69
1988	7084.54	5187.80	6818.01	8383.42
1989	6369.85	4331.49	5996.89	7565.14
1990	5727.26	3593.85	5275.58	6845.20
1991	5149.50	2957.56	4643.56	6213.59
1992	4630.02	2407.05	4089.64	5659.48
1993	4162.95	1938.92	3613.83	5183.12
1994	3742.99	1539.55	3203.63	4772.07
1995	3365.40	1197.98	2848.92	4416.26
1996	3025.90	905.30	2541.73	4107.80
1997	2720.65	641.09	2265.70	3830.81
1998	2446.19	402.90	2017.82	3582.19
1999	2199.42	188.24	1795.14	3358.94
2000	1977.54	-4.31	1595.75	3159.07
2001	1778.05	-177.88	1416.31	2979.26
2002	1598.68	-334.52	1254.73	2817.37

TABLE G-8. TIA FOR PARTICULATES, CALIFORNIA, SET 2 IMPACTS

			FORECAST	
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1975	27333.00			
1976	28466.00			
1977	19121.00			
1978	21717.00			
1979	20781.00			
1980	15288.00			
1982	13409.24	11847.19	13408.48	14969.79
1983	12056.52	10490.91	12052.92	13614.52
1984	10840.26	9234.02	10809.26	12371.41
1985	9746.70	8058.38	9670.92	11233.75
1986	8763.46	6780.69	8503.91	10071.96
1987	7879.41	5459.54	7359.30	8940.94
1988	7084.54	4122.22	6254.94	7858.55
1989	6369.85	2811.69	5204.39	6836.16
1990	5727.26	1840.41	4327.89	5970.85
1991	5149.50	1110.91	3603.46	5247.46
1992	4630.02	560.32	3006.42	4645.65
1993	4162.95	154.21	2535.52	4167.92
1994	3742.99	-134.33	2165.15	3788.49
1995	3365.40	-328.73	1874.29	3486.73
1996	3025.90	-448.14	1647.59	3247.90
1997	2720.65	-574.53	1437.24	3029.06
1998	2446.19	-702.03	1243.33	2829.16
1999	2199.42	-827.35	1064.66	2646.19
2000	1977.54	-939.80	905.85	2483.87
2001	1778.05	-1043.65	761.52	2336.68
2002	1598.68	-1140.02	630.60	2203.40

TABLE G-9. TIA FOR HYDROCARBONS, CALIFORNIA, SET 1 IMPACTS

		FORECAST		
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1975	21305.00			
1976	29292.00			
1977	14326.00			
1978	16590.00			
1979	14649.00			
1980	18482.00			
1982	13180.68	10267.47	13180.36	16093.34
1983	12226.26	9308.66	12222.35	15135.61
1984	11341.81	8384.87	11307.67	14221.45
1985	10522.14	7487.19	10436.49	13350.86
1986	9762.45	6435.49	9466.83	12384.82
1987	9058.28	5275.97	8451.97	11379.99
1988	8405.54	4018.58	7411.69	10357.46
1989	7800.43	2692.90	6363.08	9334.06
1990	7239.42	1647.46	5459.39	8443.95
1991	6719.26	820.59	4689.35	7679.54
1992	6236.94	165.60	4035.54	7025.97
1993	5789.68	-337.08	3510.05	6498.26
1994	5374.89	-706.50	3091.48	6074.38
1995	4990.19	-961.89	2760.65	5735.04
1996	4633.37	-1119.03	2503.84	5466.82
1997	4302.38	-1291.12	2253.48	5208.25
1998	3995.34	-1471.01	2011.53	4960.40
1999	3710.48	-1655.06	1777.45	4722.11
2000	3446.19	-1828.49	1558.50	4499.54
2001	3200.95	-1997.53	1347.86	4285.83
2002	2973.39	-2163.52	1145.36	4080.66

TABLE G-10. TIA FOR HYDROCARBONS, CALIFORNIA, SET 2 IMPACTS

		FORECAST		
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1975	21305.00			
1976	29292.00			
1977	14326.00			
1978	16590.00			
1979	14649.00			
1980	18482.00			
1982	13180.68	10267.81	13180.60	16093.40
1983	12226.26	9312.23	12225.09	15137.92
1984	11341.81	8418.03	11331.72	14244.62
1985	10522.14	7580.59	10496.71	13409.68
1986	9762.45	6746.72	9671.60	12584.93
1987	9058.28	5932.54	8872.08	11786.33
1988	8405.54	5139.29	8101.20	11017.07
1989	7800.43	4369.50	7361.40	10279.59
1990	7239.42	3680.68	6690.94	9610.56
1991	6719.26	3065.12	6085.27	9005.68
1992	6236.94	2514.19	5537.99	8458.71
1993	5789.68	2033.09	5056.48	7977.19
1994	5374.89	1612.24	4631.42	7551.76
1995	4990.19	1243.74	4255.20	7174.83
1996	4633.37	921.25	3922.00	6840.62
1997	4302.38	620.43	3612.13	6529.94
1998	3995.34	340.16	3324.17	6241.33
1999	3710.48	78.94	3056.32	5972.97
2000	3446.19	-163.87	2807.51	5723.72
2001	3200.95	-391.14	2574.81	5490.65
2002	2973.39	-604.38	2356.81	5272.33

TABLE G-11. TIA FOR CARBON MONOXIDE, CALIFORNIA, SET 1 IMPACTS

			FORECAST	
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1975	146097.00			
1976	175882.00			
1977	113900.00			
1978	139156.00			
1979	158223.00			
1980	146742.00			
1982	137096.55	123571.20	137096.15	150624.81
1983	132741.04	119160.92	132705.18	146244.03
1984	128110.72	113946.33	127737.03	141294.77
1985	123220.78	107679.54	122235.42	135815.93
1986	118092.71	97649.69	114540.35	128240.26
1987	112754.25	84493.28	105236.10	119274.87
1988	107239.07	68616.85	94593.90	109250.02
1989	101586.14	50854.96	82907.41	98446.59
1990	95838.69	37087.05	72320.24	88370.70
1991	90043.01	26207.88	62893.64	79189.13
1992	84246.98	17609.26	54569.97	70914.75
1993	78498.47	11014.31	47654.77	63944.21
1994	72843.81	6293.94	41966.06	58073.07
1995	67326.30	3266.18	37317.27	53112.91
1996	61984.96	1755.83	33569.35	48939.03
1997	56853.55	-48.49	29852.43	44899.61
1998	51959.91	-2012.41	26236.79	41040.28
1999	47325.62	-4050.41	22751.33	37370.15
2000	42965.95	-5903.93	19518.72	33977.14
2001	38890.18	-7643.65	16472.90	30794.47
2002	35102.00	-9295.28	13626.66	27828.61

TABLE G-12. TIA FOR CARBON MONOXIDE, CALIFORNIA, SET 2 IMPACTS

			FORECAST	
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1975	146097.00			
1976	175882.00			
1977	113900.00			
1978	139156.00			
1979	158223.00			
1980	146742.00			
1982	137096.55	123573.06	137095.69	150618.55
1983	132741.04	119204.48	132728.86	146252.44
1984	128110.72	114451.38	127998.16	141523.83
1985	123220.78	109306.98	122925.61	136453.68
1986	118092.71	103061.29	116977.66	130517.59
1987	112754.25	95979.75	110403.42	123975.40
1988	107239.07	88105.46	103307.97	116939.19
1989	101586.14	79569.62	95806.97	109526.37
1990	95838.69	71599.46	88504.84	102283.96
1991	90043.01	64170.92	81465.19	95280.68
1992	84246.98	57252.92	74716.87	88549.00
1993	78498.47	50992.41	68465.28	82299.22
1994	72843.81	45341.74	62673.46	76492.90
1995	67326.30	40263.87	57314.69	71104.04
1996	61984.96	35721.55	52373.19	66119.46
1997	56853.55	31346.89	47638.20	61349.04
1998	51959.91	27172.43	43138.98	56820.68
1999	47325.62	23218.63	38892.42	52550.17
2000	42965.95	19515.15	34917.73	48554.70
2001	38890.18	16048.57	31203.03	44822.71
2002	35102.00	12815.64	27749.70	41354.34

SECTION 10.0

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39. Conklin, Frank S., and R. Carlyle Bradshaw. 1971. Farmer Alternatives to Open Field Burning: An Economic Appraisal. Special Report 336. Agricultural Experiment Station, Oregon State University, Corvallis, Oregon. 15 pp.

40. Conklin, Frank S., and R. Carlyle Bradshaw. 1979. An Evaluation of Expected Private Losses from Selected Public Policies for Reducing Open Field Burning, Willamette Valley, Oregon. Agricultural Experiment Station, Oregon State University, Corvallis, Oregon. Circular of Information 675. 78 pp.

41. California Air Pollution Control Laws. Article 3. Meteorological Criteria for Regulating Agricultural Burning.

42. Coughlin, Robert E., John C. Keene, J. Dixon Esseks, William Tower, and Lisa Rosenburg. 19 . The Protection of Farmland: A Reference Guidebook for State and Local Governments. A Report to the National Agricultural Lands Study from the Regional Science Research Institute, Amherst, Massachusetts. U.S. Government Printing Office. 284 pp.

43. Pennsylvania Air Pollution Act. Section 4004.1 Agricultural Regulations Prohibited.

44. Intermountain Grass Growers Association. Swather, Nov.-Dec. 1981.

45. Oregon Revised Statutes, 468.453(1).

46. Oregon Field Burning: Smoke Management Program Operational Guidelines. Revised May 26, 1981. 40 pp.

47. Miller, George E. et al. 1976. A Program to Minimize the Effects of Agricultural Burning in California. Submitted to Journal of the Air Pollution Control Association, March 1976. 26 pp.

48. California Air Pollution Rules. Subchapter 2. Agricultural Burning Guidelines. Article 2. Implementation Plan 80150(d)(3).

49. Miller, George, E. Jr., and John R. Goss. 1973. Study of Abatement Methods and Meteorological Conditions for Optimum Dispersion of Particulates from Field Burning of Rice Straw. Rice Straw Incinerator Evaluation. California Air Resources Board Project No. 1-102-1. 37 pp.

50. Chilcote, D.O. and H.W. Youngberg. 1975. Non-burning Techniques of Grass Seed Residue Removal. Agricultural Experiment Station, Oregon State University, Progress Report EXT/ACS 9. 8 pp.

51. "Solid Wastes Management." 1971. Reprinted in Environmental Quality in Oregon 1971: A Summary of Current and Future Problems. Advisory Committee on Environmental Science and Technology. 4 pp.

52. Oregon. Agricultural Experiment Station. 1977. Field Burning in Oregon. Special Report 476. 24 pp.

53. Horsfield, Brian C., Clarence Becker, and Bryan M. Jenkins. 1977. Agricultural Residues as an Alternative Source of Energy for the Pacific Gas and Electric Company. Department of Agricultural Engineering Research Report, University of California, Davis, California. 293 pp.

54. Ensign, R.D., Bruce Augustin, Mark Buettner, Peter Gray, Robert Hall, and Robert Nelson. 1974. Burning and Alternative Treatments for Kentucky Bluegrass Seed Production. Progress Report No. 188, Agricultural Experiment Station. University of Idaho, Moscow, Idaho. 31 pp.

55. Ensign, R.D. and V.G. Hickey. Effects of Post-Harvest Residue Removal on Kentucky Bluegrass Growth and Development: Highlights of 8 years of Research. Progress Report No. 216, Agricultural Experiment Station, University of Idaho, Moscow, Idaho. 22 pp.

56. Rozeff, Norman and H.R. Crawford, Jr. 1980. Green Cane vs. Burned Cane Harvest Comparisons, 1978-79. In Proceedings XVII Congress, International Society of Sugarcane Technologists. Volume I. Manila, Phillipines. 1980. pp. 916-931.

57. Roberts, Darrell L. 1972. Status of the Development of a Whole Cane Cleaner. Louisiana Agricultural Experiment Station. 3 pp.

58. U.S. Agricultural Department. 1981. National Agricultural Lands Study, Final Report 1981. U.S. Government Printing Office. Washington, D.C.

59. Washington Air Act, 70.94.656. Open Burning of Field and Turf Grasses Grown for Seed - Alternatives - Studies - Funding - Procedures Limitations.

60. Freeman, Harry U. 1973. Problems and Opportunities in Management of Combustible Solid Wastes. International Research and Technology Corporation. Washington, D.C. EPA 670/2-73-056. 517 pp.

61. National Agricultural Lands Study. 1981. Interim Report Number Five. America's Agricultural Land Base in 1977. 23 pp.

62. The Futures Group. 1980. FUTURSCAN Program Manual: Trend Impact Analysis and Cost Impact Analysis. Glastonbury, Connecticut.

63. Darley, Ellis, F. 1979. Hydrocarbon Characterization of Agricultural Waste Burning. Final Report, California Air Resources Board Project A7-068-30, Statewide Air Pollution Research Center, University of California, Riverside, California. 53 pp.

64. Boubel, Richard W., Ellis F. Darley, Edward A. Schuck. 1969. Emissions from Burning Grass Stubble and Straw. Journal of the Air Pollution Control Association, (17)9:497-500.

65. Darley, E.F., F.R. Burleson, E.H. Mateer, J.T. Middleton, and V.P. Osterli. 1966. Contribution of Burning of Agricultural Wastes to Photochemical Air Pollution. Journal of the Air Pollution Control Association (11)12:685-690.

SECTION 11.0

ANNOTATED BIBLIOGRAPHY

A. AGRICULTURAL RESIDUE BURNING

B. ALTERNATIVE DISPOSAL METHODS

C. EMISSIONS FROM BURNING

D. POLICIES, LEGISLATION, REGULATIONS, AND MANAGEMENT PLANS

E. HEALTH IMPACTS

F. ENVIRONMENTAL IMPACTS

G. SOCIO-ECONOMIC IMPACTS

H. OTHER

A. AGRICULTURAL RESIDUE BURNING

1. Agricultural Residue Management: A Focus on Rice Straw. A Report of the Residue Management Task Force, University of California. 1981. 164 pp.

This report is a compendium of papers focused on the management and utilization of rice straw. Rice crop residue was selected because the chief current method of disposal, burning, is under increasing public scrutiny; because rice-straw is a massive agricultural by-product within a confined geographical area; and because the rice industry has a strong commitment to explore economically feasible alternatives to burning of rice straw.

The purpose of the report is to detail the various ramifications of the rice disposal problem and to summarize the extensive efforts to find economic uses of straw or better disposal systems. The report is directed to several areas of inquiry: the composition of rice straw, impacts of straw removal systems on the biology of rice fields, methods of field disposal, potential areas for utilization, toxicological aspects of straw removal and utilization, and an economic view of straw management systems.

INDEX: B,C,D,E,F,G

2. Allen, Thomas C., 1979. An Emissions Inventory of Miscellaneous Sources of Air Pollution in North Carolina. Department of Natural Resources and Community Development, Raleigh, North Carolina. 134 pp.

An emissions inventory of 10 miscellaneous source categories for North Carolina and for each of its counties for 1975 is presented. Included in these source categories is one for Agricultural and Land Clearing burning. Five pollutants are reported: particulate, SO_2, CO, HC, and NO_2. In addition to the emissions inventories, the emission factors and summary of the data (e.g., number of acres of various types of land use in each county) used in estimating the emissions are presented.

INDEX: C

3. Argonne National Laboratory. 1980. Illinois Biomass Resources: Annual Crops and Residues; Canning and Food-Processing Wastes. ANL/EMR-6. U.S. Department of Energy. 118 p.

This study provides a preliminary assessment of these Illinois biomass resources, including (a) an appraisal of the effects of their use on both agriculture and industry; (b) an analysis of biomass conversion systems; and (c) an environmental and economic evaluation of products that could be generated from biomass. It is estimated that, of the 39 x 10 exp 6 tons of residues generated in 1978 in Illinois from seven main crops, about 85% was collectible. The thermal energy equivalent of this material is 658 x 10 exp 6 Btu, or 0.66 quad. Illinois can strengthen its economy substantially by the development of industries that produce biomass-derived fuels and chemicals. In addition, a thorough evaluation should be made of the potential for using the state's less-exploitable land for the growing of additional biomass.

INDEX:

4. Bell, G.B. and N.E. Waggoner. 1971. "A Field Study of Air Pollution in the Lower Sacramento Valley During the 1960 Fall Season." California State Department of Public Health, Berkeley, Bureau of Air Sanitation, and California State University, Los Angeles, Division of Agricultural Sciences. November 1961. 72 pp.

The objectives established for this study included: the analysis of Sacramento's photochemical smog episodes during the 1960 fall season for possible relationship to agricultural burning; the comparative evaluation of the particulate matter brought to Sacramento by down-valley winds when significant amounts of agricultural burning occurred and when little or no burning occurred; the measurement of concentrations of oxidant, hydrocarbon, and particulate matter which characterized various pollution events occurring during the 1960 fall season; the documentation of meteorological conditions which prevailed during recognizable pollution events for comparison with similar conditions when little or no agricultural burning occurred; and, the better understanding of the principles involved and interrelationships of agricultural burning and meteorology which combine to produce visible air pollution.

Among the findings from this study were (1) smoke from agricultural burning was detectable part of the time at some smoke sampling stations north of Sacramento, but only a few periods were characterized as moderately dirty or dirty air; (2) dirty air was experienced less than 1 percent of the time during August through November at all rural stations except one which is close enough to Sacramento to be influenced by the urban pollution; (4) dirty air was experienced during all months in downtown Sacramento from August through November, variation in monthly averages was most pronounced in the urban areas, whereas those in rural areas showed little variation; and (6) in most cases the effect of smoke from agricultural fires could not be separated from the effect of particulate pollution originating from metropolitan Sacramento.

INDEX: C,F

5. California. Air Resources Board. 1981. Agricultural Burning, Acres of Waste Burned for Rice (Table). Sacramento, California. 1 p.

This table provides a monthly breakdown of rice acres burned in California by county for 1980.

INDEX:

6. Chi, C.T., and D.L. Zanders. 1977. Source Assessment: Agricultural Open Burning, State of the Art. EPA/600/2-77-107a, Industrial Environmental Research Lab, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 77 pp.

The report summarizes reported data on air emissions from agricultural open burning, used in the U.S. for field sanitation, residue removal, and residue disposal. It was estimated that the amount of agricultural open burning totaled 13.2 x 10 exp 6 metric tons (14.6 x 10 exp 6 tons) in 1973.

Using estimated emission factors derived from limited literature data, emissions were found to constitute 0.61 percent, 0.50 percent, 0.65 percent, and 0.06 percent of the national emissions of particulates, HC, CO, and NO_x, respectively. Fifteen states have emissions of at least one criteria pollutant from this source which exceed 1 percent of the state total emissions of that pollutant.

Source severity was found to be 1 for HC, 0.2 for POM, and less than 0.1 for other pollutants. (Source severity is defined as the ratio of the time-averaged maximum ground level concentration of a pollutant emitted from a representative source to the primary ambient air quality standard for criteria pollutants or to a corrected TLV for noncriteria pollutants.)

Control technology in agricultural open burning consists of practicing fire and fuel management to reduce pollutant emissions. Among alternatives to controlling emissions from open burning are the combination of mobile field sanitation and straw utilization, and incorporation of wastes into the soil.

Despite the continuing growth in crop harvest, agricultural open burning has been declining primarily due to increasing concern about air pollution from open burning and the refinement of associated agricultural practices.

INDEX: B,C,D,E

7. Chilcote, D.O. 1976. Grass seed field burning: Air Quality and agronomic aspects. Annual Meeting of the Soil Conservation Society of America. August 1976. pp. 124-126.

Brief overview of grass seed field burning in the Willamette Valley, Oregon, with discussions on emissions, management practices, alternatives to field burning, and trade-offs between burning and non-burning practices.

INDEX: B,C,F,G

8. Chilcote, D.O., H.W. Youngberg, P.C. Standwood, and S. Kim. n.d. Post-Harvest Residue Burning Effects on Perennial Grass Development and Seed Yield. 13 pp.

The purpose of this paper is to emphasize the characteristics of the burning effect and its influence on development and seed yield of temperate perennial grass crops. General areas covered are physical aspects of burning, crop yield-growth relationships, seed yield-tillering relationships, auxiliary tillering-seed yeild relationships, dry matter partitioning and tillering, seed yield components, ecological aspects, and mechanical removal versus burning. Results of research suggest that burning removes most of the crop residue and organic matter accumulation, exposing mineral-soil surfaces; causes the destruction of surviving tillers and perhaps some dormant buds, resulting in a more open canopy; and indirectly results in earlier development of more new tillers growing in more direct contact with the soil.

INDEX: F

9. Darley, Ellis F., George M. Miller, Jr., John R. Goss, and Harold Biswell. 1973. Air Pollution from Forest and Agricultural Burning. J. Fire and Flammability, Vol. 4.

The increasing use of prescribed fire in forest management and the continuing burning of agricultural crop residues creates problems in air pollution. Large scale laboratory type experiments and field trials are being conducted to evaluate yields of pollutant gases and particulates and methods for altering these emissions by varying burning practices. Ten- to fifty-pound samples of several fuel types were burned under a cone-shaped tower which simulates open burning but permits continuous analysis of total hydrocarbons, carbon dioxide, carbon monoxide, and oxygen. Grab samples were taken at two or more intervals during the fire for analysis of nitrogen dioxide and individual hydrocarbons. Particulates were collected isokinetically throughout the fires. Rate of weight loss of the burning fuel, temperature, and airflow were also recorded. From these data, yield of pollutant in lbs/ton of fuel burned were calculated. Field plots of forest floor fuels and straw and stubble from cereal crops were also burned. A 10-foot tower instrumented for temperature, carbon dioxide, and particulate was set up in plots in grain fields, and it sampled the smoke as fires burned past the tower. For both laboratory and field fires, variables presently being tested for effect on pollution are fuel type, loading, moisture level, methods of ignition, piled versus spread fuels, and head versus back fires.

INDEX:

10. Dye Seed Ranch. Garfield County: Grass Production. Washington. 24 pp.

Focuses on the current and potential production of grass seed in Garfield County. Includes information of wheat versus bluegrass prices, nationwide production of Kentucky bluegrass, and varieties of bluegrass.

INDEX: G,H

11. Field and Seed Crops: Value Per Harvested Acre, Washington, 1978-79. (Table) 1 p.

INDEX:

A. AGRICULTURAL RESIDUE BURNING (Continued)

12. "Field Burning and the Environment." Agricultural Research. September 1981. p. 12.

Very brief article on the practice of burning grass seed fields. Plant pathologist John R. Hardison, Corvallis, Oregon, is quoted as saying "What is needed is refinement of burning techniques. Improved techniques and better public understanding should enable the grass seed industry to continue this needed practice."

INDEX: B

13. Hardison, John R. 1964. Justification for Burning Grass Fields. Reprint from the Proceedings of the Twenty Fourth Annual Meeting (1964) of the Oregon Seed Growers League. pp. 93-96.

This paper discusses the justification for burning grass fields and suggests methods for reduction of the smoke nuisance. Among the advantages of burning are (1) control of disease, pests, pathogenic fungi, weeds, (2) return to soil of potash and other minerals, (3) stimulation of better yields, (4) prevention of fall heading in perennial ryegrass, and (5) low-cost removal of straw. Methods noted to reduce the smoke nuisance are (1) earlier season burning, which creates less smoke and prevents late fall concentration of burning, and (2) scheduling of burning on days when good smoke dispersal is forecasted. Other potential methods for reducing smoke might include determining optimum time of day for burning, avoidance of late season irrigation, and use of defoliants to avoid or eliminate green leaves.

INDEX: C,D,F

14. Hawaiian Sugar Planter's Association. 1982. Summary of Controlled Pre-Harvest Burning of Sugarcane Fields in Hawaii. Attachment to a letter to Douglas Kent, Pacific Environmental Services, Inc., from Don Heinz, Hawaiian Sugar Planter's Association dated January 21, 1982. 2 pp.

A very brief overview of Hawaiian sugarcane burning - its importance, extent of practice, its impact on air quality, and regulations affecting it are presented. A table shows total acreage, harvested acreage, and estimated burned acreage of sugarcane in 1980.

INDEX: C,D,E

15. Knutson, Jerry, George E. Miller, and Victor P. Osterli. 1978. Crop Residues in California - some factors affecting utilization. Division of Agricultural Sciences Leaflet 2872, University of California, Davis, California. 22 pp.

This publication lists quantities of crop residues in California by county for 1973. Both acres and tons of residue are reported. Conversion factors for tons of residue per acre, periods when crop residue becomes available and field moisture content are given.

INDEX:

16. Nordstedt, R.A., P.H. Smith, L.O. Bagnall, and F. le Grand. 1978. Sugarcane Production Residues: Technological and Economic Assessment of Methods for Conversion to Utilizable Energy Forms. DOE/USDA-19464/ 76/FR-2. Agricultural Research Service, U.S. Department of Agriculture. 82 pp.

This report examines the technological and economic feasibility of converting sugarcane production residues in South Florida to utilizable energy forms. Quantity and location of the residues are given. Current uses of the residues are outlined and compared with other potential uses which are described in the literature.

Technological problems in collection of the field residues are discussed. The resulting research and development needs are outlined.

An in-depth economic comparison of anaerobic digestion, shaft pyrolysis, and waterwall incineration is presented. Economic feasibility of each of the three processes is presented as a function of plant size using current market prices for energy and the energy price increases which would be necessary to make each of the processes economically feasible.

INDEX:

17. North Carolina Crop and Livestock Reporting Service. 1981. Agricultural Statistics. Raleigh, North Carolina. 76 pp.

This report provides information on types of crops planted, their location by county, acres harvested, yield per acre, production, and total value for the years 1979 and 1980.

INDEX:

18. O'Connell, Sean K. 1981. 1980 Annual Report on Field Burning. Oregon Department of Environmental Quality. 8 pp.

This report summarizes field burning activities, discusses the effectiveness of the 1980 Smoke Management Program, and the progress being made in discovering and utilizing alternatives to open field burning. A table showing comparative annual field burning data from 1973 through 1980 is included.

INDEX: B,D

19. Oregon. Agricultural Experiment Station. 1977. Field Burning in Oregon. Special Report 476. 24 pp.

General report that includes brief discussions on burning in Oregon on the following areas: where, who and why, the markets, legislative look, the benefits of burning, burning by machine, smoke management, alternatives to open burning, and grower and industry adjustments.

INDEX: B,D,G

20. Oregon, Air Quality Division, Department of Environmental Quality. 1980. Field Burning - A Review of Air Quality in Oregon's Willamette Valley. Portland, Oregon. 15 pp.

This report provides an overview of field burning and air quality in the Willamette Valley. The report also discusses the relationship between field burning and air quality regulations, such as emission offsets, SIP, and PSD. Also included is a discussion of relative source contribution to particulate emissions and visibility reduction in the Valley. Using the Chemical Mass Balance Analysis, vegetative burning was found to contribute 26 percent of total particulate and 49 percent of fine particulate, which contributes to visibility reduction.

INDEX: C,D,E,F

21. Oregon. Department of Environmental Quality. 1980. 1979 Annual Report of the Legislative Committee on Trade and Economic Development, Volume 16: Willamette Valley Field Burning, Research and Development. Report Series. Eugene, Oregon. 75 pp.

This report summarizes 1979 field burning program activities. Included are discussions of the effectiveness of the smoke management program, and of the progress being made, through research and development, in developing and utilizing alternatives to open field burning. Specifically, technical accounts of the field burning season are presented along with some preliminary findings from several research projects.

INDEX: B,D,E

22. Oregon State University. Agricultural Experiment Station. 1974. Oregon State University Research on Field Burning. Circular of Information 647. December 1974. 140 pp.

This report summarizes research done by Oregon State University on field burning in the Willamette Valley. Research areas covered by this report include field burning techniques and alternatives, field sanitizer development, field burning and grass disease control, field burning effects on weed control in grass seed crops and on insect pests, smoke management, straw handling, densification, and utilization, experimental pulping of grass straws, use of grass straws for animal feed, and economics of field burning and the grass seed industry in the Willamette Valley.

INDEX: B,D,G

A. AGRICULTURAL RESIDUE BURNING (Continued)

23. Owensby, C.E. 1981. Map of Kansas with hand-drawn area indicating burned area.

INDEX:

24. "The Practice of Field Burning." 1969. Reprint from Agricultural Field Burning in the Willamette Valley, Air Resources Center, Oregon State University, January 1969. 9 pp.

This report summarizes available information on agricultural field burning in the Willamette Valley. Areas of information discussed include historical background, basis for field burning, acreage and residue tonnage burned, emission content and volumes from field burning, harmful effects of field burning, research and service programs, and consideration of alternatives to field burning.

INDEX: B,C,E,F

25. Seed Crops: Acreage, Production, and Value, Washington, 1978-79. (Table) 1 pp. (Obtained from Department of Agronomy and Soils, Washington State University, Pullman, Washington.)

INDEX:

26. "Solid Wastes Management." 1971. Reprinted in Environmental Quality in Oregon 1971: A Summary of Current and Future Problems. Advisory Committee on Environmental Science and Technology. 4 pp.

Very brief overview of agricultural residues in terms of acres grown and burned, alternative disposal techniques used, and straw residues generated.

INDEX: B

A. AGRICULTURAL RESIDUE BURNING (Continued)

27. Stanford Research Institute. 1976. An Evaluation of the Use of Agricultural Residues as Energy Feedstock, Volume II. NSF/RA-760287. National Science Foundation, Washington, D.C. 595 pp.

This volume gives a nationwide county-by-county inventory of residues generated, their quantity and condition, their current uses or disposal practices, their net availability, location and distribution.

INDEX:

28. University of California, Division of Agricultural Sciences. Berkeley. 1973. Agricultural Solid Waste Disposal and Management in California. 77 pp.

This report includes an overview of the practice of field burning as a residue disposal technique. Information is provided concerning current and potential future air pollutant impacts from burning of crop residues, and the potential use of alternative disposal practices to reduce pollutants from burning. The report also summarizes current and proposed future research programs. Several tables and a map provide information on acres burned and pollutants emitted.

INDEX: B,C

29. Yamate, George. 1974. Emissions Inventory from Forest Wildfires, Forest Managed Burns, and Agricultural Burns. EPA-450/3-74-062, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 34 pp.

The objective of this project was to obtain and provide reliable data and information on acreages burned for forest wildfires, managed burns, and agricultural burning, and tons of fuel burned per acre for each of the approximately 3,100 counties and other jurisdictional entities in the country. Data and information were obtained from a large number of sources. Where source data values conflicted, adjustments were made. No estimates were made where no data whatsoever was available.

This report provides only total state and territorial summaries of acres burned and tons per acre burned. Eighteen states and territories were reported to have a positive number of acres burned, ranging from 100 (Vermont) to 974,306 acres (Georgia); 10

A. AGRICULTURAL RESIDUE BURNING (Concluded)

were reported to have no acres burned; 6 were reported to have negligible acres burned; and 21 were reported to have no data available.

INDEX:

30. Young, Alton. Air Pollution: County Burning Survey, 1959-1961. University of California, Agricultural Extension Service, Berkeley, California. 30 pp.

Surveys were conducted by Farm Advisors in 17 counties in California to determine as near as possible the actual amount of crop residue disposed of by burning in these counties. The tables show total acreage, percent area burned, acreage burning residue, average grain yield per acre, ratio grain yield to stubble, average tons per acre, and total tons burned for a variety of grain stubbles and orchard brushes.

INDEX:

B. ALTERNATIVE DISPOSAL METHODS

31. Buettner, Mark R., R.D. Ensign, and A.A. Boe. 1976. Plant Growth Regulator Effects on Flowering of *Poa pratensis* L. under Field Conditions. *Agronomy Journal* 68:410-413.

The imminent ban on fall burning of Kentucky bluegrass (Poa pratensis L.) residues has threatened the grass seed industry with subsequent reductions in yield. In order to assess the use of plant growth regulators as a potential alternative to burning, eight chemicals were applied at two developmental growth stages of unburned plots of Kentucky bluegrass. Information on panicle emergence, panicle number, and seed weight was recorded. Applications of growth regulators were made in autumn to "Merion," "Fylking," and "Nugget," and in spring to "Park" and "Baron." All treatments were applied during the second seed crop year. Increased Kentucky bluegrass seed yields are possible with selective plant growth regulators, primarily due to increased panicle numbers and seed size.

INDEX:

32. Canode, C.L. and A.G. Law. 1978. Influence of Fertilizer and Residue Management on Grass Seed Production. Agronomy Journal 70:543-546.

This article reviews research conducted to compare the effects of burning with those of mechanical residue removal on red fescue, smooth bromegrass, and crested wheatgrass. Included in this article is a brief discussion of the role of burning in grass seed production and the desirability of the mechanical removal of residue.

INDEX:

33. Canode, C.L. and A.G. Law. 1977. Post-Harvest Residue Management in Kentucky Bluegrass Seed Production. Bulletin 850. College of Agriculture Research Center, Washington State University, Pullman, Washington. 14 pp.

This article examines alternatives to open burning of residue based upon several experiments. These alternatives included various types of mechanical removal of residue and straw, open burning at low temperatures, and machine burning at different temperature levels. Also discussed is the general role of open burning in bluegrass production.

INDEX:

34. Chilcote, D.O. and H.W. Youngberg. 1975. Non-burning Techniques of Grass Seed Residue Removal. Agricultural Experiment Station, Oregon State University, Progress Report EXT/ACS 9. 8 pp.

This report discusses various alternatives to yearly open field burning of perennial and annual ryegrass fields. Alternatives include mechanical removal, incorporation, and alternate year burning. Results indicate that nonburning techniques can be grouped into two categories: those applicable to perennial grass seed crops where straw cannot be incorporated and annual ryegrass crops where both incorporation and establishment techniques can be varied.

Conclusions include (1) mechanical residue removal in perennial grasses appears to be practical in younger crop stands and in older stands of burning could be alternated with mechanical removal, however, utilization or disposition of removed residue remains an important problem, as does pest control; (2) alternate-year burning of grass fields may allow maintenance of acceptable pest control and would reduce yield losses compared to strictly mechanical removal methods in perennial grasses; (3) soil incorporation of straw during seedbed preparation in annual ryegrass is an alternative; however, weed control problems and cost are greatly increased; and (4) if a use for grass seed residue could be found which would offset the additional cost to grower, the feasibility of mechanical alternatives would be improved.

INDEX:

35. Chilcote, D.O. and H.W. Youngberg. 1975. Techniques and Timing of Post-Harvest Grass Seed Field Burning. Agricultural Experiment Station, Oregon State University. Progress Report EXT/ACS 7. 4 pp.

This report summarizes the results of research undertaken to evaluate different burning times and procedures in terms of smoke emission and impact on grass seed crop yield. Conclusions: (1) burning early in the season is preferable from the standpoint of both smoke emission and dispersion as well as subsequent seed yield, and (2) backfiring is likely to reduce emissions and work effectively when environmental and straw-stubble conditions are favorable for burning.

INDEX: C,E

36. Ensign, R.D., Bruce Augustin, Mark Buettner, Peter Gray, Robert Hall, and Robert Nelson. 1974. Burning and Alternative Treatments for Kentucky Bluegrass Seed Production. Progress Report No. 188, Agricultural Experiment Station, University of Idaho, Moscow, Idaho. 31 pp.

This is the third of a series of progress reports on Idaho Agricultural Experiment Station research related to grass seed production in northern Idaho. Research reported includes different burn practices and plant growth regulators and their effect on seed yields and plant growth and development.

INDEX:

37. Ensign, R.D. and V.G. Hickey. 1980. Effects of Post-Harvest Residue Removal on Kentucky Bluegrass Growth and Development: Highlights of 8 Years of Research. Progress Report No. 216, Agricultural Experiment Station, University of Idaho, Moscow, Idaho. 22 pp.

This is the ninth report culminating eight years of research to study the effects of field burning harvest residue of Kentucky bluegrass. Alternative methods to burning were conducted in conjunction with crop management practices. Of several growth regulators tested to replace field burning in seed production, none produced economical seed yields. On new seed fields with little residue, mechanical removal of post-harvest residue procedures produces superior seed yields to field burning. Field burning of Kentucky bluegrass was found to be the most economically viable method of removing post-harvest residue.

INDEX: G

38. Flaim, Silvio and David Urban. 1980. The Costs of Using Crop Residues in Direct Combustion Applications. SERI/TR-353-513, U.S. Department of Energy. 52 pp.

This report examines the economic feasibility of burning crop residues for on-farm grain drying, grain drying at a grain elevator, and electricity generation at a utility. Grain drying is the most economically attractive alternative studied. The cost of using crop residues in utility applications are prohibitive if the average cost of coal for utilities is used for comparison. The potential use of crop residues as a utility boiler fuel is much greater than grain drying, but relative costs depend on the specific characteristics of each application and on the accessibility and cost of coal.

INDEX:

39. Goss, John R., and Raymond H. Coppock. 1980. Producing Gas from Crop Residues. California Agriculture May 1980. (34)6:4-6.

Tests were performed to determine the potential for obtaining energy from timber and crop residues in California using a pilot producer-gas plant. Tests were run to determine the impact on air quality and showed that producer gas efficiently generated from clean fuels results in boiler stack effluent with no more impact on air quality than if the fuel were natural gas. The feasibility of using agricultural residues to generate low-BTU gas was clearly demonstrated. This report presents percent ash content for 10 different crops.

INDEX: C

40. Horsfield, Brian C., Clarence Becker, and Bryan M. Jenkins. 1977. Agricultural Residues as an Alternative Source of Energy for the Pacific Gas and Electric Company. Department of Agricultural Engineering Research Report, University of California, Davis, California. 293 pp.

This report presents the results obtained in a preliminary feasibility investigation of the potential for utilizing agricultural and forest residues produced in California as an alternative energy source for the PGEC. Four types of crop residues appear to be most promising for initiating development of this technology, including field crop residues and fruit and nut crop residues. Rice straw has the highest potential use as an alternative energy source. A survey of rice growers and fruit and nut growers have shown that growers tend to favor the idea of utilizing residues for energy.

INDEX: A,C,G

41. Miller, George E., Jr., and John R. Goss. 1973. Study of Abatement Methods and Meteorological Conditions for Optimum Dispersion of Particulates from Field Burning of Rice Straw. Rice Straw Incinerator Evaluation. California Air Resources Board Project No. 1-102-1. 37 pp.

A project was initiated in December 1970 to determine the potentials of mobile incineration as a practical means of reducing particulate emissions from combustive disposal of rice residues. Previous studies on incinerators indicated improved combustion is possible under controlled conditions. Capacity, mobility, durability, economics, wild fire control, and other problems existed. However, information on the state-of-the-art was needed under California rice field conditions because of the continuing need to reduce all contributions to the statewide air pollution problem. An experimental mobile field sanitizer (incinerator) was transported from Oregon to California. Test runs and modifications were made on the unit for use on rice field residues in California in the fall of 1971 and spring of 1972.

Results of the tests of both units indicate that the state-of-the-art technology is not sufficiently developed for use in rice field residue disposal. Projected overall costs of operation are not within the limits of economic feasibility at this time. Under reasonably good climatic conditions in California, well managed open field burns will have less particulate emissions than the incinerator tested. Under poor climatic conditions, the mobile incinerator cannot be operated in rice fields.

INDEX: C,G

42. Roberts, Darrell L. 1972. Status of the Development of a Whole Cane Cleaner. Louisiana Agricultural Experiment Station. 3 pp.

This paper summarizes work done over a 2-year period (1970 and 1971) in Louisiana toward developing a wholestalk cane cleaner. Results indicate a favorable cleaning efficiency and potential that the machine can be justified on an economic basis. However the author cautions that more research efforts are needed in this area.

INDEX: D

43. Rozeff, Norman and H.R. Crawford, Jr. 1980. Green Cane vs. Burned Cane Harvest Comparisons, 1978-79. In Proceedings XVII Congress, International Society of Sugarcane Technologists. Volume I. Manila, Phillipines. 1980. pp. 916-931.

In compliance with the Texas Air Quality Control Board Order for the Co-op to search for harvesting alternatives to burning, CLAAS 1400 harvesters were operated and evaluated under actual production conditions in 812 green hectares and 3687 burned hectares. In comparison with burned cane, the green cane sustained a 7.41 percent sugar recovery loss and increased production costs 9.2 percent by reducing harvester, in field transport, trucking and milling efficiencies. Vegetative material left after harvesting in green fields was 2.37 times than that left in burned fields. This constituted a major problem for subsequent farming operations.

INDEX:

B. ALTERNATIVE DISPOSAL METHODS (Concluded)

44. Sloane, G.E. and L.J. Rhodes. 1972. A Comparison of the Processing of Burned and Unburned Sugarcane. Experiment Station, Hawaiian Sugar Planter's Association. Hawaiian Planter's Record, Volume 58, No. 14, 1972. 10 pp.

A series of five tests was conducted in the fall of 1971 to determine the impact of unburned can on harvesting and processing operations. The tests showed that harvesting and hauling requirements increased, while processing rates were reduced, in some tests substantially so. Factory recovery changed very little although there was a slight increase in tons 96 DA sugar/acre for unburned cane, presumably because of lower cane cleaner losses. Sugar refinability was generally poorer when processing unburned cane.

INDEX: G

45. United States, Department of Agriculture. 1978. Improving Soils with Organic Wastes. 167 pp.

Chapter 2 of this report looks at crop residues and their relationship to agricultural soils. Proper use of crop residues provides a highly effective means for controlling soil erosion and sediment transport, for reducing nutrient losses through runoff to streams, and for supplying organic matter to maintain good soil tilth. Quantities of crop residues produced, their nutrient content, and current usage are presented. Costs of collection, processing, transportation, and application of crop residues, competitive uses (animal feed, energy, and industrial uses) are briefly discussed. Research needs are also outlined.

INDEX: A

C. EMISSIONS FROM BURNING

46. "Air Quality in Oregon." 1971. Reprinted in Environmental Quality in Oregon 1971: A Summary of Current and Future Problems. Advisory Committee on Environmental Science and Technology. 5 pp.

A brief overview of quantity of emissions from the open field burning of grass straw is presented. Principal air pollution problem is the suspended carbon and ash particulates of smoke, which may average 15 pounds per ton of straw burned. Research underway to find beneficial uses for the straw is also summarized.

INDEX: E,F

47. Ajax, P. and R.E. Lee, Jr. 1976. Non-Pesticidal Air Pollution from Agricultural Process. In Air Pollution from Pesticides and Agricultural Processes. CRC Press. Cleveland, Ohio. pp. 227-251.

Summarizes emissions from grass field and crop residue burning and factors that affect such emissions. Tables provide summary of emission factors.

INDEX: A

48. Boubel, R.W. Summary of Atmospheric Emission Data from Grass Field Burning Tests. Reprint: Agricultural Field Burning in the Willamette Valley. Air Resources Center, Oregon State University, January 1969. 4 pp.

This reprint summarizes in six tables proximate analyses of grass stubble and straw emissions from burning the residue of grasses in field and in laboratory studies.

INDEX:

49. Boubel, Richard W., Ellis F. Darley, and Edward A. Schuck. 1969. Emissions from Burning Grass Stubble and Straw. Journal of the Air Pollution Control Association, (17)9:497-500.

The emissions from burning the residue following grass-seed harvest were determined by means of a combined laboratory-field study. Samples of the straw and stubble residue were burned in the laboratory burning tower at the University of California at Riverside. Complete analyses were determined for gaseous and particulate emissions for the important grass species from the Willamette Valley of Oregon. Particulate emissions averaged 15.6 lb/ton of fuel burned. Carbon monoxide averaged 101 lb/ton of fuel burned. Hydrocarbon emission averages, in pounds per ton of fuel burned, were 1.74 for saturates plus acetylene, 2.80 for olefines, and 1.68 for ethylene. The NO emission, at the temperature peak during the burn, averaged 29.3 ppm. Field studies, conducted by personnel from Oregon State University, measured only particulate emissions, carbon dioxide, and temperature over the burn. The carbon dioxide values were found to be similar to those obtained on the burning table at UCR, and it was therefore concluded that the other gaseous emissions were similar and could be used as reasonably accurate for emission inventories. The temperature values obtained in the laboratory and field were also similar and further justifies extrapolating the burning table data to field situations. The particulate matter collected in the field studies averaged 15.55 lb of particulate per ton of fuel burned. This is the same average obtained for the burning table data which again serves to validate the emissions reported from Riverside. Much more variability was found in the particulate emissions obtained in the field which reflects the wider range of environmental conditions encountered in the field.

INDEX:

50. Bucon, Harry W., Joseph F. Macko, and Harold J. Taback. 1978. Volatile Organic Compound (VOC) Species Data Manual. EPA-450/3-78-119 U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Section 5-01-002 presents the following information on agricultural waste burning: factors that affect emissions from open burning; emission factors for hydrocarbon emissions from a variety of field, weed, orchard, and vine sources; basic controls available to control emissions; and a composite profile of hydrocarbon specie emissions.

INDEX:

51. California. Air Resources Board. 1981. Agricultural Burning. (Assorted Tables). Sacramento, California. 10 pp.

These tables provide the following information by county for "all crops" burned in California: tons of waste burned, acres of waste burned, tons of particulate emissions produced, tons of hydrocarbon emissions produced, and tons of carbon monoxide emissions produced.

INDEX: A

52. Carrol, John J. 1973. Determination of Temperature, Winds, and Particulate Concentrations in Connection with Open Field Burning. Final Report. California Air Resources Board Contract ARB-2114. 100 pp.

An investigation of plume rise and smoke characteristics from open field burning of agricultural residues is reported. Plume behavior was studied photographically and visually as a function of local wind and temperature structure and fire type.

Plume rise from an open field burn is very sensitive to both wind speed and to fire type. The choice of an optimal fire strategy depends on whether total emissions are to be minimized or if ground level concentrations downwind of the source are to be minimized. The size distributions of the particulates as a function of local wind and temperature structure and fire type were also studied.

Two appendices are included containing sample soundings of the vertical distribution of temperature, wind, absolute humidity, and particulate concentrations; and data on the particulate concentrations and size distributions (for particles larger than 0.4 microns in diameter) for individual fire plumes. The results are summarized as a qualitative analysis of plume rise from various types of fires under various meteorological conditions and as quantitative averaged comparisons of particulate emissions and their physical characteristics with fire type.

INDEX:

53. Compilation of Air Pollution Emission Factors (Revised). 1977. OAP Publication No. AP-42. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

INDEX:

54. Daniels, P. Anders. 1980. Air Pollution and Emission Values for Agricultural Burning in Hawaii. Department of Meteorology, University of Hawaii. UHMET 79-10. May 1980.

To estimate ambient pollution concentration levels and prepare control strategies, particularly for suspended particulates and carbon monoxide, the Hawaii Department of Health relies on the "proportional" air quality model which requires emission rates for all sources in the area as one of the inputs. A burn tower test was therefore conducted for sugar cane and pineapple trash. Questions were however raised as to whether the rather vigorous field fires can be simulated in a burn tower. A field survey was therefore undertaken where pollutants were sampled downwind of burning fields. A diffusion model--basically a limited Gaussian line source model--was developed and run, using the data collected during the burns. The calculated emission rates for suspended particulates and carbon monoxide are orders of magnitudes larger than the burn tower rates. This is attributed to dust sucked up by the fire for particulates and to oxygen starvation at the center of the fire for carbon monoxide.

NOTE: Comments concerning this report are available in a letter plus attachment from Edward J. Lui, Head of the Engineering and Environmental Affairs, Hawaiian Sugar Planters' Association to Dr. Anders Daniels, dated October 1, 1979.

INDEX: A

55. Daniels, A. and W. Bach. 1977. An Agricultural Burning Pollution Simulating Model. (UHMET 77-3), The International Union of Air Pollution Prevention Association, The Fourth International Clean Air Congress, Contribution II-51, 4 pp.

This paper describes a field pollution sampling program of sugar cane and pineapple burns and the subsequently developed diffusion simulation model.

NOTE: For comments on this paper, contact Mr. Don J. Heinz, Hawaiian Sugar Planters' Association.

INDEX:

56. Daniels, Anders, Wilfred Bach, and Karl How. 1975. Prediction of Air Pollution Concentrations from Agricultural Burning. (UHMET 75-3), Air Pollution Control Association, 68th Annual Meeting, Contribution 75-26.4. 11 pp.

This paper describes a source-oriented air pollution monitoring program for agricultural burning in Hawaii and presents a simulation technique for estimating field emission rates and ambient pollutant concentration levels. Several samples were used to obtain a number of independent estimates of field emission rates. Although individual estimates showed considerable variation, the average calculated emission rate was close to that obtained from a burning tower test. The advantage of the simulation approach as compared to burning tower studies is that not only emission rates, but more importantly, ambient pollutant levels can be assessed.

C. EMISSIONS FROM BURNING (Continued)

NOTE: For comments on this paper, contact Mr. Don J. Heinz, Hawaiian Sugar Planters' Association.

INDEX:

57. Darley, Ellis F. 1977. Emission Factors from Burning Agricultural Wastes Collected in California. Final Report, California Air Resources Board Project 4-011, Statewide Air Pollution Research Center, University of California, Riverside, California. 77 pp.

This project was initiated to determine the pollutant emission factors from burning 31 field, vine, and orchard crops and weeds in an out-of-doors, instrumented burning tower. The pollutants of concern were particulates, carbon monoxide, and hydrocarbons. Size distribution of smoke particles was also determined.

Field crops and weeds were burned as head and back fires at an air dry moisture level. Orchard and vine crops were burned in piles at two moisture levels and two systems of ignition in which the second pile of a pair was rolled on the embers of the first fire. As a class, field crops and weeds produced considerably more of all three pollutants than did orchard and vine crops. Back firing field crops resulted in lower emissions of particulates when compared with head firing but this was not so for carbon monoxide or hydrocarbons. There was no additional significant reduction of particulate or carbon monoxide obtained by drying most orchard crops below about 35 percent moisture (dry weight basis); there was a further reduction of hydrocarbon, but the change was quite small. Rolling orchard fuel onto existing fires significantly increased emissions in most cases, but again the changes were relatively small. Most particles from all fires were submicron in size. Back firing produced significantly smaller particles than did head firing. Additionally drying orchard fuels had no real effect on particle size but the roll-on orchard fires produced significantly larger particles than the first fire of the pair.

INDEX:

C. EMISSION FROM BURNING (Continued)

58. Darley, Ellis F. 1979. Hydrocarbon Characterization of Agricultural Waste Burning. Final Report, California Air Resources Board Project A7-068-30, Statewide Air Pollution Research Center, University of California, Riverside, California. 53 pp.

This project was initiated primarily to determine hydrocarbon speciation and emission factors from burning residues of eight selected field and orchard crops in an out-of-doors, instrumented burning tower; factors for particulate, carbon monoxide, and total hydrocarbon were calculated, as is normal for such projects. In addition, for the first time from such burning, factors were determined for oxides of nitrogen, sulfur dioxide, and some aldehydes.

Field crops were burned as head and back fires, and orchard crops were burned in piles. Emissions of particulate, CO, and total hydrocarbons were considerably less from orchard than from field crops. Methane constituted more than 50 percent of the hydrocarbons below C_6 from both residue types, with olefins making up about 33 and 25 percent, respectively; more than 70 percent of the olefin was ethylene. Some 17 hydrocarbons above C_6 were detected, but yields were extremely small, exceeding 0.5 pounds in only a few instances and usually being less than 0.1 or even 0.01 pounds per ton of fuel burned. More than 70 percent of the oxides of nitrogen from both residue types appeared as NO, the yields of NO and NO_2 being about 2.4 and 0.8 pounds per ton, respectively. No direct measurement of SO_2 was possible but sulfur losses during the burning of the two crop types averaged 1.4 and 0.3 pounds per ton, respectively. Not all of this went to SO_2, but if it had, maximum yields would be double these figures. Detection of aldehydes was very erratic and not altogether reliable. Three compounds were found with some regularity, varying from 12 pounds to less than a few tenths of a pound per ton of fuel burned.

INDEX:

59. Darley, E.F., F.R. Burleson, E.H. Mateer, J.T. Middleton, and V.P. Osterli. 1966. Contribution of Burning of Agricultural Wastes to Photochemical Air Pollution. Journal of the Air Pollution Control Association (11)12:685-690.

Agricultural wastes from orchards, grain fields, and range lands are burned each year in California as the most practical means of ridding the land of these wastes. In order to determine the relative contribution of the burning of such material to photochemical air pollution, the effluent from 123 fires of known weights of range brush, both dry and green, barley and rice stubble, and prunings from various fruit and nut trees were monitored in a special tower which provided an open burning situation. Analyses were made for total hydrocarbon, expressed as C, by flame ionization detection, and for 24 individual hydrocarbons by gas chromatography, as well as for CO and CO_2 by infrared spectroscopy. A few analyses were made for oxides of nitrogen. These data, coupled with temperature and airflow measurements, allowed calculations to be made on pounds of effluent per ton of material burned and demonstrated that the emissions from agricultural burning are much less than those from the automobile, a principal source of such emissions.

INDEX: A

60. Darley, Ellis F., and Shimshon L. Lerman. 1975. Air Pollutant Emissions from Burning Sugar Cane and Pineapple Residues from Hawaii. EPA-450/3-75-071, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 30 pp.

Emission factors for particulate matter, carbon monoxide, and hydrocarbons from the burning of whole sugar cane, sugar cane leaf trash, and pineapple leaf trash from Hawaii in an instrumented burning tower were determined. Analyses of benzo(a)pyrene and several trace metals were made from a few whole cane fires. Particle size distribution of particulate matter was determined in two sugar cane leaf trash fires. About 90 percent of the particles were less than 0.5 microns in diameter. Yields of pollutants from these sources were compared with the yield from a number of other agronomic crops.

INDEX:

61. Darley, Ellis F., Shimshon L. Lerman, George E. Miller, Jr., and James F. Thompson. 1976. Laboratory Testing for Gaseous and Particulate Pollutants from Forest and Agricultural Fuels. Air Quality and Smoke from Urban and Forest Fires: International Symposium. National Academy of Sciences, Washington, D.C. pp. 78-89.

This report describes a laboratory approach to determine emission factors, how emissions might be minimized by modifying burning practices, and results of preliminary studies on the size and morphology of the particles in smoke. Emissions from rice straw and particle size distribution of smoke from citrus prunings burning and from head fires of rice and of sugar cane leaves are reported.

INDEX:

62. Darley, Ellis F., George E. Miller, Jr., John R. Goss, and Harold H. Biswell. 1974. Air Pollution from Forest and Agricultural Burning. California Air Resources Board Project No. 2-017-1. 86 pp.

This project was initiated to obtain information on the effect of atmospheric conditions, residue management, and fire management techniques on particulate, hydrocarbon, and carbon monoxide emissions from open field burning. Burns were conducted with cereal grains such as wheat, rice, and barley; asparagus fern and orchard prunings. Many burns were conducted in the field, and laboratory simulations of field burns were done at the SAPRC burning tower. Both laboratory and field data agreed that moisture content of fine fuel residues was the most significant factor influencing emission levels. At higher moisture contents particulate emissions can be reduced by lighting the field only on the downwind edges (backfiring) or using an into-the-wind striplighting technique. Particulates were analyzed for size distribution and percent fraction soluble in chloroform. Residue drying rates were measured to aid in predicting when a particular residue would be dry enough to burn. Costs of various fire management procedures were determined, and cultural recommendations to reduce emissions are given.

INDEX: G

63. Gikis, Benjamin J., F. Alan Ferguson, Jerry L. Jones, M.C.T. Kuo, Clyde L. Witham, Shirley B. Radding, Jean S. Smith, Constance T. Warmke, Katherine A. Miller, John A. Alich, and Peter D. Steat. 1978. Preliminary Environmental Assessment of Energy Conversion Processes for Agricultural and Forest Product Residues, Volume I. EPA-600/7-78-047. U.S. Environmental Protection Agency, Cincinnati, Ohio.

This report compares the relative environmental effects, including emissions, of agricultural residue conversion systems with the most likely alternative sources of energy. Crop residues included in this study came from rice, cotton, barley, sugarcane, wheat, sunflower, and corn. Crop residue densities were plotted on a map. Data on pesticide and herbicide usage and residue levels for each crop residue studied were collected and evaluated. In most cases, the residual levels were quite low and are probably not significant to the environment.

INDEX: A,E,F

64. Goss, John R., and George E. Miller, Jr. 1973. Study of Abatement Methods and Meteorological Conditions for Optimum Dispersion of Particulates from Field Burning of Rice Straw. Spring Open Field Burning Trials. California Air Resources Board Project No. 1-101-1. 46 pp.

The project was initiated to obtain information on the effect of meteorological conditions and management techniques on particulate emissions from spring open field burning of rice field residue. Two fire management practices were employed: single line backfire, and single line headfire. Three residue management techniques were studied: spread straw, windrowed straw, and raked spread straw. In addition, measurements were taken of air temperature, relative humidity, absolute humidity, wind speed and direction, residue moisture content, residue loading, fire temperature, rate of flame spread, CO_2 emission, particulate production and particulate size distribution.

The data analysis showed that particulate emissions could be minimized by burning at low moisture contents and using a backfire instead of a headfire ignition technique. Laboratory simulations confirmed the advantages of low residue moisture and backfiring in reducing particulate emissions. The laboratory tests also showed that increased fuel loadings may help to decrease particulate emissions. Laboratory and field data showed that the particulate emissions were generally of a submicron size and a significant amount of the particulates were chloroform-soluble organic compounds.

Studies were conducted with several large open field burns where the practicality of selected fire and residue management techniques were tested. The estimated costs per acre of the various techniques were confirmed in the large open field burns.

INDEX: A,G

C. EMISSIONS FROM BURNING (Continued)

65. International Research and Technology Corporation. 1973. Problems and Opportunities in Management of Combustible Solid Wastes. EPA-670/2-73-056. U.S. Environmental Protection Agency. Cincinnati, Ohio. 517 pp.

This study considers the cost and immediate environmental impacts of waste management, the extent to which material or energy can be recovered from waste, the markets for such recovered resources, and the use of federal procurement and other incentives and disincentives to encourage resource recovery. Disposition of crop wastes are discussed and tables indicating residue factors for a large number of crops are given.

INDEX: B

66. Southerland, James H. and Audrey McBath. n.d. Emission Factors and Field Loading for Sugar Cane Burning. Unpublished report, U.S. Environmental Protection Agency. 8 pp.

This report briefly discusses some of the associated problems uncovered by the review of emission factors and field loading factors for pre-harvest burning of sugar cane crops to determine the appropriateness of such factors as applied to sugar cane grown in Florida rather than in Hawaii.

INDEX:

67. Texas Air Control Board. 1975. Compliance Division. Summary from The Effects of Sugar Cane Burning on Ambient Air Quality in the Lower Rio Grande/Report on Data from Hi-Vol Sampling During the Burning of Sugar Cane Fields. 1 p.

Total suspended particulate measurements at five sites near sugar cane fields in the Lower Rio Grande Valley and at three sites remote to these fields were made from December 1974 through March 1975 by the Texas Air Control Board. Simultaneously over 19,000 acres of cane were burned in the Valley as part of this year's sugar cane harvest. However, under the conditions of these burns, the suspended particulate levels in this part of Texas show no measurable increase due to these burns.

The total suspended particulate levels measured were compared to the only health-related ambient air quality standard relevant to this type of source, the national ambient air quality standards for total suspended particulates. These standards were not violated according to these measurements. Whatever air pollution problems may be associated with sugar cane burning, under the conditions of the 1973 and 1974 harvests, they do not cause the violation of an ambient air quality standard.

INDEX: C

68. Wayne, L.G., and M.L. McQueary. 1975. Calculation of Emission Factors for Agricultural Burning Activities. EPA-450/3-75-087, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Proposed revisions to the emission factors for the burning of wine and orchard crops, weeds, and forest residues activities given in Sections 2.4 and 6.12 of AP-42, Compilations of Air Pollutant Emission Factors, are made. The data calculations, and supplemental information, upon which the proposed emission factors are based, are provided.

INDEX:

D. POLICIES, LEGISLATION, REGULATIONS, AND MANAGEMENT PLANS

69. Garvin, Anthony O. 1977 Legislative Control of Pesticidal Air Pollution. In Air Pollution from Pesticides and Agricultural Processes. Robert E. Lee, Jr. (ed.). CRC Press. Cleveland, Ohio. pp. 217-226.

This article reviews existing federal legislation affecting pesticide use or manufacture, and discusses the difficulties and potential for applying such legislation to pesticidal air pollution. Major conclusion is that the regulatory mechanisms for controlling the adverse effects of pesticidal air pollution already exist in present federal legislation, despite the fact that neither the Federal Insecticide, Fungicide, and Rodenticide Act nor the Clean Air Act was designed with such pollution in mind.

INDEX:

D. POLICIES, LEGISLATION, REGULATIONS, AND MANAGMENT PLANS (Continued)

70. Georgia, Department of Natural Resources. 1980. Rules for Air Quality Control. Chapter 391-3-I, revised November, 1980.

INDEX:

71. Hawaii Air Pollution Regulations. (Hawaii Environmental Laws and Regulations, Volume II, Public Health Regulations, Department of Health, Chapter 43, Air Pollution Control; Adopted January 21, 1972; Amended September 13, 1972, Effective December 21, 1972; January 15, 1973, Effective July 27, 1973; February 13, 1976, Effective May 13, 1976.)

INDEX:

72. Intermountain Grass Growers Association. Swather. July 1981.

Includes articles on burning programs in Idaho and Washington and field burning research on smoke management in Oregon.

INDEX: C

73. Intermountain Grass Growers Association. Swather, Nov.-Dec. 1981.

Includes new Idaho "right to farm" bill that affects open burning, and review of 1981 burn season.

INDEX:

74. Louisiana Air Control Commission. 1981. Air Quality Regulations with Amendments.

INDEX:

75. Miller, George E. et al. 1976. A Program to Minimize the Effects of Agricultural Burning in California. Submitted to Journal of the Air Pollution Control Association, March 1976. 26 pp.

Nearly 4 million tons of agricultural residues are open burned each year in California. This burning is a significant source of hydrocarbon, carbon monoxide, and particulate emissions in certain areas of the state. The agricultural community and the State of California have supported research on the subject of minimizing these emissions. A program has been developed from this research and Air Resources Board meteorological studies to reduce the impact of this burning on air quality consisting of three parts: (1) regulations to control the methods and times of burning based on field and laboratory burning research; (2) declaration of permissive-burn and no-burn days for given areas based on meteorological data and the expected impact of agricultural burning on these areas; and (3) limitation of the maximum acreage that can be burned on any day. The paper concludes with a preliminary evaluation of the effectiveness of the current program and recommendation of possible improvements that might be made in the program.

INDEX: A,C,F

76. Miller, George E., John J. Carroll, James F. Thompson, John R. Goss, and Ellis F. Darley. 1973. Minimizing Visible Emissions from Agricultural Burning. California Air Environment (4)1:4-6.

A number of factors that affect visible emissions are discussed. These factors include four residue management techniques, three fire management practices, and moisture content of the residues. Recommendations are then made how to minimize adverse effects on the environment from open-field burning of most field residues.

INDEX: C

77. Mississippi. Bureau of Pollution Control, Department of Natural Resourcces, 1981. Air Quality Regulations. Regulation APC-S-1, Air Quality Regulations for the Prevention, Abatement, and Control of Air Contaminants.

INDEX:

D. POLICIES, LEGISLATION, REGULATIONS, AND MANAGMENT PLANS (Continued)

78. Nebraska. 1980. An Act relating to the State Fire Marshal; to amend Section 81-538, Revised Statutes Supplement, 1978; to clarify a penalty provision; to authorize a ban on open burning as prescribed; to provide a waiver; to provide a penalty; to repeal the original section; and to declare an emergency. Legislative Bill 810.

INDEX:

79. North Carolina, General Assembly. 1981. An Act to Rewrite and Relocate G.S. 14-139 Relating to Setting Fires in Certain Areas. Chapter 1100, House Bill 878. Raleigh, North Carolina. 9 pp.

This bill adds a new section, Article 4C, "Regulation of Open Fires", under which agricultural open burning in North Carolina is regulated.

INDEX:

80. North Dakota. Chapter 33-15-04. Open Burning Restrictions, Section 33-15-04-02. Permissible Open Burning.

INDEX:

81. Oregon. Department of Environmental Quality. 1981. Agricultural Operations: Agricultural Burning. Chapter 340. Revisions adopted March 13, 1981.

Oregon regulation of agricultural burning including a table that shows field burning acreage quotas.

INDEX:

82. Oregon. Department of Environmental Quality. Field Burning in the Willamette Valley, 1977-1978. Volume 10. 36 pp.

This report discusses significant field burning activities during 1977 and 1978. Included herein are legislative and rule making reviews, an operational program description, burning accomplishments, and related air quality measurement as affected by various weather regimes. Presented are several tables showing, for example, acres burned by date, fire district burning quotas and acres burned, and daily burning and air quality summary. Smoke complaints are also included.

INDEX: A

83. Oregon. Field Burning Regulation. Oregon Revised Statutes 468.450-468.495 (Hand engrossed 10-1-79)

INDEX:

84. Oregon Field Burning: Smoke Management Program Operational Guidelines. Revised May 26, 1981. 40 pp.

These guidelines pertain to field burning in the Willamette Valley. Topic areas include Background: grass seed industry, climatology, acreage, smoke-sensitive areas, principal parties; Control of Burning: registration, permits, daily acreage control, radio advisors, enforcement; and Management of Burning: meteorological data, determination and allocation of acreage for burning, control of emissions, and use of air quality data. Attachments are provided including, in part, one showing a flow diagram for the determination of acreage release.

INDEX: A,C,F

85. Texas Air Control Board. Regulation I (31 TAC Chapter 111) Control of Air Pollution from Visible Emissions and Particulate Matter. Revised March 20, 1981.

INDEX:

E. HEALTH IMPACTS

86. Environmental Health Resource Center. 1978. Advisory Report on the Potential Health Effects of Leaf Burning. Document Number 78/19. Illinois Institute of Natural Resources, Chicago, Illinois. 28 pp.

The health effects of leaf burning depend on five primary factors: the number and constitution of the population exposed; types of pollutants emitted; the effects of individual pollutants and their combinations; the quantity of pollutants emitted, and the duration of exposure to those pollutants.

Clearly, the quantification of the potential health effects of leaf burning is a complex problem. Nonetheless, many underlying factors have been studied, and some information is available that permits consideration of such effects.

INDEX:

87. Hanlen, Richard C., and Lyle D. Calvin. 1981. Preliminary Health Effects Study: Analysis of Hospital Admissions Data. Technical Report, Department of Statistics, Oregon State University, Corvallis, Oregon. 17 pp.

A study was undertaken to evaluate the relationships, if any, between ambient smoke "dose" and public health "response". A test group (respiratory diagnosis codes) and a control group (circulatory disease diagnosis codes) were specified in an attempt to detect a relationship between smoke intrusion and in-patient admission. The ambient smoke dose was measured in Lebanon, Oregon, by nephelometer readings as an indication of smoke dose intrusion, and hospital inpatient information was recorded from the Lebanon Community Hospital. Patients admitted were assumed to be from the smoke intrusion area. Statistical tests were performed and did not provide any statistical evidence of an effect. The authors expressed that the size of the effect appears so small at this time as to make the extra effort to conduct another survey with a much larger control group (300-400 as compared to 62 patients in this study) questionable.

INDEX:

88. O'Connell, Sean K. 1978. Design Considerations in Planning a Health Effects Study of Field Burning. Department of Environmental Quality, Field Burning, Portland, Oregon. 6 pp.

This report is a brief discussion of the conceptual and technical elements that need to be considered in the design of a major health effects study. Included is a review of the pertinent literature and the specific problems that can be expected, a discussion of some general considerations of the specific components of such a study, and recommendations.

INDEX:

89. Smith, Terry. A Cookbook for Short-Term Health Effects Studies. Prepared for the Field Burning Health Effects Subcommittee, Department of Environmental Quality, Portland, Oregon. 9 pp.

This report is a general discussion of methods for determining the health impact of field- and slash-burning smoke in the southern Willamette Valley. Each of the five components of a full study--1) aerometric data (what's in the air), 2) possible test populations (the people to be studied), 3) selection of health end points (the change in health to be monitored, 4) surveillance methods (method for detecting change in health), and 5) analysis methods--are discussed separately, and then several study designs are described. Finally, there are some suggestions for how to proceed in developing an actual study, conducting a one-day workshop, and awarding a contract.

INDEX:

90. Srivastava, N., and L.D. Calvin. 1979. A Study of Pulmonary Lung Function as Measured Under the Oregon Lung Association's Christmas Seal Breathmobile Program, 1972-1977. Department of Statistics, Oregon State University, Corvallis, Oregon. 24 pp.

This study compares 5 pulmonary lung functions of various populations in Oregon, generated on the basis of several environmental factors, including the comparison of these functions in the Willamette Valley of Oregon, which is subject to field burning, with values in other regions of Oregon. The data was collected over the period from November 1972 to 1977.

E. HEALTH IMPACTS (Concluded)

Statistical tests were performed to determine whether there was any statistical difference between the lung function values obtained in the Willamette Valley with those obtained in other regions of Oregon. The results varied depending upon the lung function. For example, the t-test for equality of means showed that the one-second-forced-expiratory-volume lung function was significantly higher for the Willamette Valley versus all other regions. However, there was no significant differences for the percent-of-the-forced-vital-capacity-expired-in-the-first-second lung function.

INDEX:

91. Terraglio, Frank P. 1978. Memorandum to Field Burning Subcommittee on Health Effects. Department of Environmental Quality, Portland, Oregon. 6 pp.

Results of the mutagenicity assays of high volume filter samples collected in Springfield and Eugene, Oregon, during periods of field smoke intrusions in 1977 are presented. Enclosed is a memorandum briefly discussing the mutagenic assays performed on the samples. Overall the results show little mutagenic activity.

INDEX:

92. Young, William H 1979. Agenda Item No. L, October 19, 1979, EQC Meeting, Information Report: Status of Research on the Public Health Effects of Field Burning Smoke. Memorandum to Environmental Quality Commission, Portland, Oregon. 7 pp.

This memorandum summarizes progress being made to date in Oregon on the study of public health effects of field burning smoke. The current status of health information studies is briefly discussed. Findings are summarized for three investigations: 1. The characterization of the physical/elemental properties of field burning and slash burning smoke, and smoke intrusion, 2. the mutagenicity of field burning smoke particulate, and 3. regional differences in public (respiratory) health through retrospective analysis of available statewide lung function data. Specific components for a successful research program in health effects and four specific research activities planned for implementation in the coming year are discussed.

INDEX: C

F. ENVIRONMENTAL IMPACTS

93. Ota, Asher. 1970. Entomological Aspects of Burning (Hawaii). Experiment Station, HSPA. July 1970. 3 pp.

This paper presents a brief summary of readily available literature on the entomological effects of burning in sugarcane fields and the author's personal views on the entomological effects of nonburning. The author concludes that (1) the burning of sugarcane trash contributes significantly in reducing beetle borer populations, (2) without burning, the borer problem should become worse and may necessitate the use of modern insecticides, (3) if modern pesticides are widely used, we probably will substitute chemical pollution for air pollution by burning, and (4) the use of insecticides on sugarcane in Hawaii should be avoided if at all possible.

INDEX:

G. SOCIO-ECONOMIC IMPACTS

94. Burt, L.A. and M.E. Wirth. 1976. Economics of Grass Seed Production in the Inland Pacific Northwest. Bulletin 835. College of Agriculture Research Center, Washington State University. Pullman, Washington. 25 pp.

This bulletin reports the results of a questionnaire used to obtain information on the general characteristics of the eastern Washington and northern Idaho grass seed industry. Grower reaction to a ban on open field burning and attitudes on production alternatives were emphasized. A break even analysis was made to study the effects on grower net returns from changes in grass seed yield and net price. Included general background discussion of the grass seed industry in the area.

INDEX: A,D

95. Conklin, Frank S. 1975. Some Economic Consequences of Densifying, Handling, and Storing of Willamette Valley Grass Straw. Oregon Agricultural Experiment Station Technical Paper 4043. Presented at the World Straw Conference, Eugene, Oregon, May 5, 1975. 6 pp.

This paper discusses briefly technically viable uses for grass straw, prospects for marketing straw in these uses, and the economic issues pertinent to the use of straw in these markets, and compares eight straw densification alternatives. General conclusions include the technical viability of straw for various uses and the lack of knowledge concerning the viability of markets for straw in these uses.

INDEX: B

96. Conklin, Frank S. 1976. Adjusting to Air Quality Standards: A Contrast Between Grower and Industry Effects in Grass Seed Production. Oregon Agricultural Experiment Station Technical Paper 4255. 19 pp.

This paper presents expected initial economic losses and longer-run expected adjustments in the grass seed industry in Oregon's Willamette Valley associated with five policy alternatives. Using a quadratic programming algorithm, expected initial cropping pattern changes, income loss effects to individual grass seed producers, and reduction in air emissions were estimated for each policy. Of the five policy alternatives evaluated, the phase acreage reduction associated with Senate Bill 311 appears to be least disruptive in terms of producer income losses, and gets high marks in terms of air emission reductions. The nonburn/no sanitizer choice achieved best air emission reductions but was poorest in terms of producer income losses. The paper concludes with the author's predictive judgments on expected crop, grower, and industry adjustments.

INDEX: A,B,C,D

97. Conklin, Frank S. November 23, 1981. Letter. 2 pp.

The difficulty in quantitatively separating air emission sources and placing an economic value upon health effects from such sources is more than simply an information gap. It involves (1) incapability of technically separating a number of air quality pollutants, (2) identifying the nature and magnitude of health gains from identifiable levels of improvement in air quality, and (3) inability to place an economic value upon the trade-offs between health and industry losses. Public health gains or losses, both quantitatively and economically, are the much more difficult issue.

INDEX:

98. Conklin, Frank S. and R. Carlyle Bradshaw. 1971. Farmer Alternatives to Open Field Burning: An Economic Appraisal. Special Report 336. Agricultural Experiment Station, Oregon State University, Corvallis, Oregon. 15 pp.

The purpose of this study was to evaluate the economic impact of suggested technical choices for open burning of grass seed crops. While not exhaustive, it does include the choices that are most often suggested: alternative land use (extensive crops, intensive crops, forage-livestock production), soil incorporation of residues, mobile field sanitizer, and mechanical residue removal followed by field sanitization. Technical and economic data were collected from available published sources. Also included are brief, general discussions on the case for open field burning, air pollution, and a need for alternatives.

INDEX: A,B,D

99. Conklin, Frank S. and R. Carlyle Bradshaw. 1979. An Evaluation of Expected Private Losses from Selected Public Policies for Reducing Open Field Burning, Willamette Valley, Oregon. Agricultural Experiment Station, Oregon State University, Corvallis, Oregon. Circular of Information 675. March 1979. 78 pp.

The objective of this report is to assess initial expected economic impacts on individual grass seed producers from a selected number of public policy choices suggested for reducing open field burning. A quadratic programming algorithm was used to model a commercial grass seed farm. Quantitative comparisons showed considerable differences in expected or probable economic impacts to growers among the public policy choices. Policy effects would not be felt uniformly across growers in the Willamette Valley, with greatest effect on farms having a high percentage of poorly-drained lands relative to those having higher proportion of medium and well-drained lands. Additional study is needed on the full spectrum of private and social gains and losses from reduction of open field burning.

INDEX: A,B, D

100. Conklin, Frank S., and Herbert H. Stoevener. 1977. An Inquiry into Means for Evaluating Gains and Losses Associated with Changes in Air Quality in Oregon's Willamette Valley in the Private and Public Sectors. Department of Agricultural and Resource Economics, Oregon State University, Corvallis, Oregon. 5 pp.

This paper identifies five components necessary for measuring private and social gains and losses from alternative air quality control policies, summarizes the state-of-the-art in quantifying gains and losses, and makes four recommendations for a research program relating air quality to health effects.

INDEX:

101. Folwell, R.J., L.A. Burt, and M.E. Wirth. 1978. An Econometric Analysis of the United States Kentucky Bluegrass Seed Industry. Technical Bulletin 90, College of Agriculture Research Center, Washington State University, Pullman, Washington. 19 pp.

This bulletin specifies and estimates an econometric model of the U.S. bluegrass seed industry and uses it to estimate changes in the industry, both short- and long-run, resulting from changes in various factors including yields per acre. Data are included on acreages from 1963 through 1975 for the inland Pacific Northwest region and for Oregon.

INDEX: A

102. Nickell, L.G. 1970. Comparisons of Burning vs. Non-Burning of Cane: I. Field. Experiment Station, Hawaii Sugar Planter's Association. Paper No. 260. 10 pp.

This paper reports the findings of the first three tests, conducted by the Hawaiian Sugar Planter's Association, to estimate the effect of non-burning versus burning. In all three tests, results indicated tons sugar per acre were less on the unburned fields than on the burned fields (14.87 vs. 11.34; 7.3 vs. 6.9; and 11.27 vs. 10.57).

INDEX: A

103. Oregon State University. Agricultural Experiment Station. 1973. Economic Characteristics of Farms Producing Grass Seed in Oregon's Willamette Valley. Circular of Information 643. November 1973. 82 pp.

The objectives of this study were to (1) identify and describe physical and economic characteristics of farms which produce grass seed in the Willamette Valley with special emphasis upon those factors which appear to exert the greatest influence upon profitability and resource use among grass seed growers, and (2) establish benchmarks of profitability for grass seed operations to serve as inputs in subsequent research efforts which will seek to evaluate the grass seed industry as it adjusts to an environmental pollution ban on open field burning.

While noting that future trends are problematic and beyond the scope of the study, general conclusions drawn from the results of this study include (1) threat of the January 1, 1975, burning ban will hasten exodus by some 20 percent or more of the grass seed growers who are not able to do much more than cover operating costs and do not perceive an increase in the size of their operation as an attractive alternative, and (2) the grass seed industry's importance as an industry in the Valley is not likely to change significantly as a consequence of a burning ban.

INDEX: B,D

104. Oregon State University. Agricultural Experiment Station. 1975. Rye Grass Straw Utilization in Paper and Fiberboard Products: An Exploratory Investigation. Circular of Information 648. January 1975. 22 pp.

This research report provides an initial investigation into the economic feasibility of using straw as a substitute fiber for wood in the manufacture of pulp and paper in the Pacific Northwest. This report includes comments on the potential to substitute straw for wood, and vice versa. It also presents comparisons of fiber costs, capital costs, and manufacturing costs for four products. The marketability of rye grass straw-based products are unknown at this time. It seems unlikely that large straw-based manufacturing plants would be considered attractive investments by the private sector unless technology advancement and relative prices of raw materials existing in 1972 were to be altered markedly.

INDEX: B

105. Oregon State University. Agricultural Experiment Station. 1976. Cost and Returns of Grass Seed Production in Oregon's Willamette Valley, 1959 to 1975. Special Report 464. October 1976. 47 pp.

The purpose of this study was to measure the economic history of eight major grass seed types produced during the 17-year period from 1959 through 1975. The seed types analyzed are annual ryegrass, perennial ryegrass, orchard grass, tall fescue, bentgrass, fine fescue, Merion Kentucky bluegrass, and other Kentucky bluegrass. Results show that farm gate prices and yields for grass seeds have varied widely from year to year and have been the major contributors to gross income instability for the Willamette Valley grass seed industry over time. Results also showed that average returns from grass seed production were generally low, and often negative. It was generally concluded that the grass seed industry would survive the current air quality regulations and would continue to face economic pressures over time as do all industries.

INDEX:

106. Tu, J.C. 1970. Comparisons of Burning vs. Non-burning of Cane: II. Factory-Refinability. Experiment Station, Hawaii Sugar Planter's Association. Paper No. 260. 5 pp.

This paper presents a comparison of the quality characteristics of juice, syrup, and sugar from burned and unburned cane. It was found that based on quality characteristics the juice and syrup from burned cane is of superior quality to the juice and syrup from unburned cane. It is hard to draw a line between the burned and unburned cane with respect to sugar quality. Since an excess of cane trash has an adverse effect on sugar quality, the unburned cane is less suitable or desirable for sugar production as far as sugar quality is concerned.

INDEX:

107. Vars, Charles R., Jr. and Gary W. Sorenson. 1972. Study of the Economic Effects of Changes in Air Quality. EPA-R5-72-006. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. 279 pp.

A summary is presented of the research results of a three-year study of the economic effects of changes in air quality in the Willamette Valley. The study specified a pollution can be evaluated, as well as generated new testable hypotheses concerning the effects of air pollution on consumer activity. Implementation of the benefit-cost methodology consistent with the conceptual model and its associated hypotheses focused on the estimation of the various benefits and costs of controlling smoke produced by open burning of grass seed fields in the Willamette Valley. Eight appendices are attached which present theoretical and empirical materials, new, generally unappreciated theoretical results and empirical investigations which tested important hypotheses.

INDEX:

H. OTHER

108. Coughlin, Robert E., John C. Keene, J. Dixon Esseks, William Toner, and Lisa Rosenburg. 19 . The Protection of Farmland: A Reference Guidebook for State and Local Governments. A report to the National Agricultural Lands Study from the Regional Science Research Institute, Amherst, Massachusetts. U.S. Government Printing Office. 284 pp.

The intent of this guidebook is to provide a reference guide to programs that are being used to protect agricultural land. Information has been compiled on the programs as to state and local experience with them, their intended and unintended effects, their fiscal and political costs, and their long- and short-run effectiveness.

109. Freeman, Harry M. 1973. Problems and Opportunities in Management of Combustible Solid Wastes. International Research and Technology Corporation. Washington, D.C. EPA 670/2-73-056. 517 pp.

This study assesses the cost and immediate environmental impacts of waste management, the extent to which material or energy can be recovered from waste, the markets for such recovered resources, and the use of federal procurement and other incentives and disincentives to encourage resource recovery. The amounts of combustible solid wastes presently generated by agriculture and other activities are described and future waste flows projected. The report reviews technologies that utilize or dispose of these wastes, identifying the more promising ones. Finally, the report examines governmental strategies to promote resource recovery or improve disposal, and recommends a preferred strategy for accomplishing these ends.

INDEX:

H. OTHER (Concluded)

110. U.S. Agricultural Department. 1981. National Agricultural Lands Study, Final Report 1981. U.S. Government Printing Office. Washington, D.C.

This report summarizes information on the United States agricultural resources in the following areas: (1) the agricultural land base, including potential cropland and changes within the agricultural land base; (2) regional perspectives of agricultural land conversion; (3) competition for agricultural lands from outside agriculture, including demographic changes and new economic opportunities; (4) competition for agricultural lands from within agriculture, for example demand for gasohol from corn; and (5) current efforts to protect agricultural lands at local, state, and federal government levels.

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